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ENVIRONMENT AND WATER RESOURCES

FRACTURED BEDROCK TECHNICAL IMPRACTICABILITY EVALUATION REPORT

MISSOURI ELECTRIC WORKS (MEW) SITE
CAPE GIRARDEAU, MISSOURI

PREPARED FOR:

MEW Site Trust Fund Donors

C/O Ameren Services

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TABLE OF CONTENTS

TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

ARAR	Applicable or Relevant and Appropriate Requirements
bgs	Below Ground Surface
BHHRA	Baseline Human Health Risk Assessment
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CD	Consent Decree
COC	Constituents of Concern
COPC	Chemicals of Potential Concern
CSM	Conceptual Site Model
ERT	Electrical Resistance Tomography
EPM	Equivalent Porous Medium
ESD	Explanation of Significant Differences
FS	Feasibility Study
GRAs	General Response Actions
GTARC	Groundwater Target Concentrations
HI	Hazard Index
ICs	Institutional Controls
Komex	Komex H2O Science, Inc.
MCL	Maximum Contaminant Level
MDNR	Missouri Department of Natural Resources
MEW	Missouri Electric Works
MNA	Monitored Natural Attenuation
MW	Monitoring Well
NCP	National Oil and Hazardous Substances Contingency Plan
NPL	National Priorities List
O&M	Operation and Maintenance
OSWER	Office of Solid Waste and Emergency Response Programs
PCBs	Polychlorinated Biphenyls
PCE	Tetrachloroethene
ppm	Parts Per Million
RAO	Remedial Action Objective
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
RL	Reporting limit
RME	Reasonable Maximum Exposure

ROD	Record of Decision
SDWA	Safe Drinking Water Act
STD	Site Trust Fund Donors
TCE	Trichloroethene
TCL	Target Cleanup Levels
TI	Technical Impracticability
TSCA	Toxic Substances and Control Act
ug/L	Micrograms Per Liter
USEPA	United States Environmental Protection Agency
VOCs	Volatile Organic Compounds
WQS	Water Quality Standards

1 INTRODUCTION

This Fractured Bedrock Technical Impracticability (TI) Evaluation Report (TI Report) was prepared by Komex-H2O Science, Inc. (Komex) on behalf of the Missouri Electric Works Site Trust Fund Donors (MEWSTD) for the MEW Site (Site) in Cape Girardeau, Missouri (**Figure 1.1**).

This report should be read in conjunction with the Groundwater Remedial Investigation Report (RI) (Komex, 2005a), Draft Groundwater Modeling Report (Komex, 2003a), Groundwater Modeling Letter Report (Komex, 2005b), Report for Baseline Human Health Risk Assessment (BHHRA) (Komex, 2005c), and Bedrock and Alluvium Groundwater Remediation Feasibility Study Report (FS Report) (Komex, 2005d).

This report follows the guidelines for evaluating TI as provided in the Guidance for Evaluating the Technical Impracticability of Ground-Water Restoration (Office of Solid Waste and Emergency Response Programs [OSWER] Directive 9234.2-25) (USEPA, 1993).

1.1 REPORT PURPOSE

This TI Report forms part of a phased Site environmental investigation, which includes preparation of the FS Report (Komex, 2005d). This TI Report was prepared to provide data to assist the United States Environmental Protection Agency (USEPA) in rendering a decision on the technical impracticability of achieving certain identified Applicable or Relevant and Appropriate Requirements (ARARs), within a reasonable time frame (30 years), for groundwater in bedrock impacted from sources at the Site.

Under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), an alternative selected to address contamination at a site must achieve the ARARs identified for the action or provide the basis for waiving the ARARs. ARARs may be waived for any of six reasons including where compliance with the requirement is technically impracticable from an engineering prospective. The term engineering perspective refers to factors such as feasibility, reliability, scale or magnitude of a project, and safety.

USEPA Guidance for Evaluating the Technical Impracticability of Groundwater Restoration, (USEPA, 1993) specifies the following components as necessary for a TI evaluation:

1. Specific ARARs or media standard for which TI determinations are sought;

2. Spatial area over which the TI decision will apply;

3. Conceptual site model (CSM);

4. An evaluation of restoration potential; and

5. Proposed remedy option cost estimates.

In developing the TI Report, the range of groundwater remedial alternatives for the fractured bedrock evaluated in the FS (Komex, 2005d) was considered. The FS evaluated feasible bedrock groundwater remedial alternatives against the set of nine National Oil and Hazardous Substances Contingency Plan (NCP) criteria, as prescribed in the NCP under Section 300.430 (e) 9 (iii) (NCP, 1995). The evaluation demonstrated that, of the bedrock remedial alternatives developed and retained for detailed evaluation, none were able to fully satisfy the NCP criteria "Compliance with ARARs." The FS determined that the evaluated remedial alternatives for bedrock would not be able to reduce constituent of concern (COC) concentrations below chemical specific ARARs/Target Cleanup Levels (TCLs) within a reasonable time frame (30 years). This analysis is summarized in Section 5.0 of this report.

1.2 ORGANIZATION OF THE REPORT

This TI Report is organized into the following sections in accordance with the USEPA TI guidance document (USEPA, 1993):

- **Section 1.0 – Introduction.** Describes the purpose of the TI Report and provides background information such as, Site description, history, and previous environmental activities completed.

- **Section 2.0 – Identification of ARARs/ Media Cleanup Standards.** Identifies the specific ARARs/groundwater cleanup standards for the identified COC in which the TI decision is being sought.

- **Section 3.0 – Bedrock TI Zone.** Delineates the horizontal and vertical extent of the area that is fixed in space for which the TI determination is being sought, including both area and depth in relative terms.

- **Section 4.0 – Conceptual Site Model.** Presents a conceptual model of the Site, including site geologic and hydrogeologic factors; contaminant sources and releases; and contaminant distribution, transport and fate parameters.

- **Section 5.0 – Evaluation of Restoration Potential.** Demonstrates that source control measures have been implemented to the extent practicable; provides a predictive restoration time analysis which identifies assumptions and uncertainties; and demonstrates that no other conventional or innovative technologies can attain ARARs/cleanup standards within a reasonable time frame.
- **Section 6.0 – Proposed Bedrock Remedial Alternative Cost Estimates.** Estimates present worth of construction and operation and maintenance costs of the proposed remedial alternatives.
- **Section 7.0 – Protectiveness of Proposed Remedial Alternative.** Presents an alternative remedial strategy if the TI Waiver is granted.

1.3 BACKGROUND INFORMATION

The Site-specific soil cleanup levels, as documented in the Record of Decision (ROD) (USEPA, 1990) that define, for the purposes of this report, the area of the Site, were 10 parts per million (ppm) Polychlorinated Biphenyls (PCBs) for soils to a depth of 4 feet below ground surface (bgs), and 100 ppm at depths greater than 4 feet bgs.

For the purposes of this report, the physical extent of the property where MEW conducted operations will be referred to as "the Property." The Site includes an area on and off the Property and has a total surface area of approximately 6.8 acres. In addition to the terms "the Site" and "the Property," reference may be made to the "Study Area," which is defined to include all of the Property, all of the Site, and areas outside of the Site, where remedial investigative actions have been performed.

A description of the Property and Property history is summarized below. A detailed description is provided in the Draft Groundwater Design Investigation Work Plan (Komex, 2002a).

1.3.1 PROPERTY DESCRIPTION

The Property is located at 824 South Kingshighway in a commercial area of Cape Girardeau, Missouri. The Site location map is provided as **Figure 1.1**. The Property occupies a 6.4-acre tract of land, which is bound to the north and east by retail and office properties, to the south by retail properties and to the west by South Kingshighway.

South Kingshighway provides access to the Property via an asphalt-paved drive that lies in front of a single concrete building and extends partway around the south side of the Property. The building occupies the northwest corner of the Property and is currently used by the owner to store equipment. The remainder of the Property consists of gravel-paved roads, grass covered areas, and wooded ravine and fence line areas.

1.3.2 SITE HISTORY

MEW operated at this Property between 1953 and 1992. During this operational period MEW sold, serviced, and rebuilt transformers, electrical motors, and electrical equipment controls. Operations included recycling of materials from old equipment and the recovery of copper wire and dielectric fluid from transformers. In total, approximately 16,000 transformers were repaired or scrapped at the Property during the period of operation. Approximately 90 percent of the transformers dielectric fluid was recovered and filtered through Fuller's Earth prior to reuse. Some dielectric fluid is unaccounted for and it is estimated that the total volume of unaccounted dielectric fluid is on the order of 28,000 gallons.

1.3.2.1 Regulatory History

The regulatory compliance and litigation history of the Site is summarized below. A detailed discussion of the Site regulatory history is presented in the ROD (USEPA, 1990).

- **October 1984** - The Missouri Department of Natural Resources (MDNR) inspected the MEW facility and discovered leaking drums containing dielectric fluid. Elevated concentrations of PCBs were detected in oil-stained soil samples collected during the inspection.
- **November 1984** - The USEPA, pursuant to the Toxic Substances and Control Act (TSCA), inspected the MEW facility and found that MEW handling and storage procedures for oils containing or contaminated with PCBs did not conform to regulations. Soil sample results indicated elevated concentrations of PCBs.
- **August 2, 1988** - The USEPA issued an Administrative Order requiring MEW to perform several response actions, specifically to notify the public of the contamination; minimize the exposure of the public to PCB-impacted dust, soil or sediment; and minimize the amount of PCB-impacted soil migrating from the Site in surface water runoff. The USEPA erected barriers across the drainage ditches to reduce the migration of PCB-impacted soil offsite.
- **December 30, 1988** - Administrative Order on Consent between MEW Steering Committee and the USEPA (Docket No. 7-89F-002).
- **February 21, 1990** - The Site was listed on the National Priorities List (NPL).
- **September 28, 1990** - The USEPA issued the ROD, which set forth the selected soil and groundwater remedies for the Site, including on-site incineration for the cleanup of PCB-impacted soil, a pump and treat system to treat impacted groundwater, and additional

investigations to identify data that would be necessary for the design of the groundwater remediation system.

- **December 30, 1991** - A Consent Decree (CD), signed by the USEPA, the MDNR, 175 Settling Defendants, and three federal agencies, was filed with the Federal Court for the Eastern District of Missouri, Southeastern Division.
- **August 29, 1994** - The Federal Court for the Eastern District of Missouri, Southeastern Division approved the CD.
- **October 1994** - CD entry was appealed by a group of non-settling former MEW customers.
- **February 1, 1995** – The USEPA issued an Explanation of Significant Differences (ESD) to the ROD, which documented primary changes to the ROD, including changing onsite incineration to onsite thermal desorption and defining onsite thermal treatment to be either incineration or thermal desorption.
- **August 1995** - The Eighth Circuit Court of Appeals reversed the entry of the CD and remanded the CD to the Federal District Court for further deliberation.
- **August 14, 1996** - The CD was approved a second time by the Federal District Court. The same group of former customers again appealed the CD entry.
- **December 1997** - The Eighth Circuit Court of Appeals confirmed the entry of the CD.
- **March 9, 1998** – The CD entered into effect.

1.3.2.2 Previous Site Investigation and Remedial Activities

Numerous site investigations and limited remedial activities have been conducted at the Site since 1987; these are summarized below. Additional information/data relating to these activities is provided in the RI Report (Komex, 2005a).

- **1985 Investigation. March 31, 1986 CH2MHill**
- **1987 - Ecology and Environment**; In response to the USEPA-directed field investigation program, six groundwater monitoring wells were installed at the Property (monitoring wells MW-1 to MW-6). Monitoring wells MW-1, MW-2, MW-5, and MW-6 were installed in the surficial loess deposits at depths not exceeding 41 feet bgs. Monitoring wells MW-3 and MW-4 were installed in the Plattin Limestone at depths not exceeding 60 feet bgs. Wells MW-1 and MW-2 have since been abandoned; the abandonment dates were not documented.
- **1988 - USEPA**; Erected barriers across the drainage ditches to reduce the migration of PCB-impacted soil offsite.

- **1990 - Earth Tech**; Installed five monitoring wells (MW-6A, MW-7, MW-8, MW-9, and MW-10) (**Figure 1.2**). These wells were all completed in the Plattin Limestone at depths not exceeding 63 feet bgs, the first significant groundwater-bearing zone encountered at the Site.
- **1991 - Earth Tech**; Installed two additional groundwater monitoring wells in the Plattin Limestone (wells MW-11 and MW-11A) (**Figure 1.2**). Well MW-11 was installed to a depth of 120 feet bgs, and well MW-11A was installed to a depth of 405 feet bgs.
- **Between July 1999 and July 2002 - Williams Environmental Services, Inc**; In accordance with the ROD (USEPA, 1990) completed a remedial action, which included the excavation and remedial treatment of PCB-impacted soils from surface to a maximum depth of 27 feet bgs at the Site. Impacted soils were treated by thermal desorption to a cleanup level of 10 ppm for surface and subsurface soil.
- **June 2000 - Komex**; Conducted a geologic and hydrogeologic investigation at and within the vicinity of the Site (Komex, 2001a). The following tasks were conducted as part of this investigation:
  - Site reconnaissance and field mapping;
  - Fractured rock lineament study;
  - Groundwater and sediment sampling from groundwater monitoring wells;
  - Laboratory analyses of groundwater and sediment samples;
  - Installation of three groundwater data loggers in groundwater monitoring wells MW-3 (screened from 21 to 31 feet bgs), MW-11 (screened from 115 to 120 feet bgs), and MW-11A (open below 319 feet bgs);
  - Quarterly collection of data logger data which recorded groundwater levels and precipitation measurements;
  - Initial bedrock fracture modeling; and
  - Initial groundwater conceptual model development.
- **September 30, 2000**; Well MW-8 was abandoned due to a damaged wellhead.
- **April 2001**; Quarterly groundwater monitoring undertaken by EarthTech ceased in 1991 (EarthTech, 1991). Komex re-initiated an ongoing quarterly groundwater-monitoring program in late 2000 and quarterly monitoring reports were prepared throughout 2001 (Komex, 2001b; Komex, 2001c; Komex, 2002b). In 2002 the first two quarters of groundwater monitoring data were incorporated into the Draft Groundwater Design Investigation Work Plan (Komex, 2002a) with subsequent monitoring results distributed as data packages (Komex, 2003b; Komex, 2003c; Komex, 2003d; Komex, 2003e).

- **Between November 2002 and October 2003**; Komex, in accordance with the Draft Groundwater Design Investigation Work Plan (Komex, 2002a), conducted a two-phase groundwater design investigation. Results of this investigation are presented in the RI Report (Komex, 2005a). The following tasks were conducted as part of this two-phase investigation:
  - Assessment of Site hydrological characteristics through analysis of the well hydrographs in combination with precipitation data;
  - Geoprobe investigation to assess and refine the geophysical interpretation;
  - Geophysical electrical resistivity tomography (ERT), seismic reflection and refraction assessment on and to the southeastern extent of the Site, in the vicinity of the on-site well cluster (MW-3/5/11/11A), to enhance the understanding of the fracture networks and flow regime and to identify target locations for the installation of future groundwater monitoring wells;
  - Installation and subsequent groundwater and sediment sampling of three groundwater-monitoring wells (MW-12, MW-13 and MW-14) (**Figure 1.2**), located in the southeast corner of the Site. The locations of the wells were based on the findings of the geoprobe investigation and geophysical assessment. The monitoring wells were completed within the fractured limestone at depths of between 57 and 95 feet bgs and have been monitored over five events to date;
  - Additional geophysical surveys (electrical resistivity and seismic velocity) to the southeast of the Site, which includes the wetland area, were undertaken to: 1) identify fracture networks potentially connected to the Site, 2) define basement topography, and 3) identify target locations for the installation of groundwater monitoring wells to provide constraints for groundwater modeling and target probable impacted locations;
  - Advancement of eleven boreholes to assist in guiding groundwater monitoring well installation. Boreholes BH-15B1 through BH-15B5 were advanced to assist in locating wells MW-15A and MW-15B; boreholes BH-16A1 and BH-16B1 were advanced to assist in locating the MW-16 well cluster; and boreholes BH-17B1 through BH-17B4 were advanced to assist in locating wells MW-17A and MW-17B;
  - Installation and groundwater sampling of eight additional groundwater-monitoring wells (MW-15A, MW-15B, MW-16A, MW-16B, MW-16C, MW-17A, MW-17B and MW-18) (**Figure 1.2**) located south of the Site and within the wetland area. Wells MW-16A, MW-16B, MW-16C, MW-17A, and MW-18 were completed within alluvial deposits, and wells MW-15A, MW-15B and MW-17B were completed within the fractured limestone. These wells were sampled in September and October, 2003;

- Installation of a groundwater piezometer, MEW-E1, in the drainage way southeast of the Property;
- Installation of groundwater data loggers in groundwater monitoring wells MW-16A and MW-16C to determine vertical groundwater flow in the wetland area; and
- Update of the conceptual model.

- **2004** - Komex conducted an additional investigation, which involved the installation of five groundwater monitoring wells (wells MW-20A, MW-20B, MW-20C, MW-21A and MW-21B) in the alluvial sediments in the wetland area, to the southeast of the Site (**Figure 1.2**). The investigation was designed to study the movement of COPCs within the alluvium (potentially an alluvial channel). Groundwater monitoring was also conducted in February, May, August, and November of 2004.

2 IDENTIFICATION OF ARARS/TARGET CLEANUP LEVELS

This section presents the ARARs for the COC for which a TI waiver is sought. Chemical-specific ARARs were identified in the FS and included the Federal Safe Drinking Water Act (SDWA) maximum contaminant levels (MCLs), the MDNR (Missouri Department of Natural Resources) MCLs (State MCLs), the MDNR Water Quality Standards (WQS), and the MDNR Groundwater Target Concentrations (GTARC).

MCLs and State MCLs are established drinking water standards for public drinking water supply systems. Typically, for a given compound, the MCLs and State MCLs are the same. In some instances, the State MCLs may be set at a lower concentration than MCLs, or State MCLs may be established for a compound, which does not have an established Federal MCL. WQS are standards established by the State of Missouri for the protection of groundwater for designated uses. The GTARC are conservatively derived risk-based target concentrations for groundwater remediation of voluntary cleanup sites in Missouri, which are relevant and appropriate in the absence of promulgated MCLs or State MCLs.

TCLs for the Site, as developed in the FS Report (Komex, 2005d), were chosen to be equivalent to the MCLs (for COC which have established MCLs) because they are legally enforceable standards for drinking water. In the case of COC with State MCLs, which are more restrictive than MCLs, the State MCL is identified as the TCL. In the case of COC without a promulgated MCL/State MCL, the TCL is chosen to be WQS, GTARC, risk-based levels, or the laboratory analytical reporting limit (RL), whichever is greatest.

The COC and chemical-specific ARARs/TCLs for which a TI waiver is requested are all chemicals which were included as COPC in the BHHRA, as presented in Table 2.1.

3 BEDROCK TI ZONE

This section describes the proposed horizontal and vertical extents over which any possible forthcoming TI decision would apply (Bedrock TI Zone). This includes the portion of groundwater in the fractured bedrock known or suspected of possibly containing COC that would require substantial timeframes (e.g. greater than 100 years) to remediate using bedrock remedial technologies evaluated and retained in the FS Report.

3.1 RATIONALE

Selection of the Bedrock TI Zone was made based on the information available describing the distribution, occurrence, and behavior of COC within the fractured bedrock. In Section 4.0 of this report, a detailed conceptual model of the hydrogeology and COC behavior in fractured and solution-enhanced bedrock at the Site is provided. As discussed in Section 4.0, one of the key factors in setting the Bedrock TI Zone is the inherent unpredictability in migration of COC within the fractures. The fracture network, which has been characterized by a variety of field methods (discussed in more detail below and in Komex, 2005a), comprises a complex set of partially interconnected dominant vertical orthogonal fracture sets (trending roughly northeast-southwest and southeast – northwest – see below and in the RI (Komex, 2005a) for more detail, with fracture density, length and aperture all decreasing with depth. Near-horizontal bedding plane fractures are also present, predominantly within a few feet of the upper bedrock surface, but their density decreases markedly with depth. Presently available data suggest that COC transport and groundwater flow is dominated by the vertical features in the Site area, especially at greater depths when active horizontal fracture density drops substantially, and overburden pressure contributes to smaller apertures, however these features may represent a transport pathway of some significance.

As described in the RI, locating COC within the bedrock has been challenging. Considerable effort has been expended to locate individual vertical fracture features, which have the greatest likelihood of containing and transmitting COC, with only partial success. A good example is the installation of well MW-12, which targeted a major NW-SE trending fracture believed to be a possible conduit for carrying COC from the onsite MW-3 well cluster area, where known elevated concentrations of COC have been repeatedly measured, to the property boundary and offsite. The location for the well was selected based on geophysical surveys and fracture modeling (see Komex, 2005a). This well was cored and successfully intercepted a major vertical fracture feature. Sampling revealed that groundwater within the zone of influence of this fracture contained elevated levels of chlorobenzene (the highest yet recorded onsite) and other

COC. However, well MW-13, located using similar methodology, was installed in what was believed to be a parallel major NW-SE trending fracture feature located only a few feet away from well MW-12, has contained negligible levels of COC (see Komex, 2005a). Similarly, well MW-15B located downgradient of the Site along fracture trend with well MW-12, appears to have been successfully completed within the identified major vertical fracture zone itself (or within the effective fractured zone around the feature), but to date has yielded only very low (estimated J-flag level) values of COC. This illustrates the inherent complexity and heterogeneity of the fracture network, and also the complex and unpredictable migration patterns of COC within that network. This has been evaluated by a series of Monte-Carlo simulations of particle flow through a statistical representation of the fracture network at the Site, based on the collected fracture data from outcrop, detailed mapping of quarry exposures in the vicinity and core data (Komex, 2005a and Komex, 2003a). What these simulations show is that in a series of equally likely fracture networks (all of which honor the available data), particles of COC released at source zones at the Site can take many different pathways downgradient from the Site. These particles move generally in a downgradient fashion, but along the orthogonal northeast to southwest fractures, where intersections and geometry allow COC to spread in those directions as well. What is also apparent is that within the core of the so-called "plumes," that there will be many fractures which may not be impacted by COC, even though nearby fractures may be impacted. This type of unpredictable behavior also results in significant mixing of COC at fracture intersections, particularly between un-impacted and impacted fractures, which tends to dilute COC concentrations. The combination of these effects results in lateral spreading and dilution in selected fractures. This requires that the Bedrock TI Zone be extended laterally beyond the point normally suggested by an equivalent porous medium (EPM) approach.

3.2 SUGGESTED BEDROCK TI ZONE

Based on the rationale above, the suggested Bedrock TI Zone, as shown on **Figure 3.1**, comprises a block of weathered and fractured bedrock of approximately 1,150 feet by 1,000 feet in area, by 175 feet deep. This block is oriented such that the longitudinal axis is aligned with the interpreted groundwater flow direction (roughly to the southeast) at the Site. The lateral and longitudinal dimensions of the Bedrock TI Zone were selected to include the areas of measured COC concentration above TCLs for the Site (see FS Report, 2005d), from approximately 80 feet upgradient of the known source areas and to the downgradient area where groundwater discharges at depth from the fractures to the alluvium. This Bedrock TI Zone also includes sufficient volume around the known areas of impact to provide a "buffer zone" to allow for the variability of the fractured bedrock system, and transport in directions oblique to the dominant groundwater flow direction, as discussed above.

The depth of the proposed Bedrock TI Zone is the upper 175 foot thickness of weathered and fractured bedrock. This zone is proposed to extend from the top of the first bedrock surface to 175 below that initial bedrock contact. The rationale for this zone is based on observations that fracturing and groundwater flow in the deep bedrock zone is relatively insignificant and the limited hydraulic conductivity of the deeper bedrock (this is discussed in more detail in the RI (Komex, 2005a), and in Section 4.0 of this report).

4 CONCEPTUAL SITE MODEL

The CSM serves as a foundation for evaluating the restoration potential of the Site. It includes the site geology and hydrogeology, nature and extent of COC in groundwater, fate and transport processes, and current and potential receptors. The RI (Komex, 2005a), Draft Groundwater Modeling Report (Komex, 2003a) and Groundwater Modeling Letter Report (Komex, 2005b) are the primary sources of information for this section. This CSM reflects the current understanding of the Site.

4.1 GEOLOGY

Geology at the Site and surrounding areas consists primarily of loess, "terrace" and "alluvial" deposits underlain by Plattin Formation Limestone. A detailed discussion of the geologic conditions present at the Site and surrounding areas is presented in the RI Report (Komex, 2005a). The general characteristics of the surficial soils and bedrock are discussed in the following sections.

4.1.1 SURFICIAL GEOLOGY

The native, surficial soils consist of 15-25 foot thick Pleistocene loess underlain by brownish-red gravelly clay, which is derived from the weathering degradation of the underlying Plattin Formation Limestone (limestone residuum soil), at the Site, to "terrace" and "alluvial" deposits in the wetland area. The United States Geological Survey (USGS) map of surficial geology (**Figure 4.1**) depicts the Pleistocene loess within the vicinity of the Site, generally present on higher ground and "terrace" and "alluvial" deposits present in the valley areas, which supports this change in surficial geology.

The Pleistocene loess beneath the Site is classified as the Menfro silt, which is comprised of firm brown silty clay that is easily eroded, and characteristically develops on loess-covered ridge tops and hillsides of 5 to 9 percent slope. The Menfro silt extends to an average depth of 15 feet bgs in the area of the Site with clay content generally increasing with depth. The Menfro silt has a high water capacity, and moderate permeability and surface runoff.

The majority of the Property has been excavated to remediate PCB-impacted soil within the Menfro silt and limestone residuum, which lay at depths ranging from 0.5 and 27 feet bgs. The excavated soils were thermally treated and subsequently used to backfill the excavations. The thermally treated soil has a lower cohesive-bonding strength; therefore, this soil is more easily eroded. The treated soil also appears to be more permeable.

Surficial soils in the wetland area, to the southeast of the Site, include "terrace" and "alluvial" deposits consisting of rounded sands, silty sands with occasional discontinuous clay layers near wells MW-16A, MW-16B, MW-16C, MW-20A, MW-20B, MW-20C, MW-21A, MW-21B, and silty clay, clayey silt, sandy silt and silty sand near soil boreholes BH-19A through BH-19I. The alluvial deposits range in thickness from 9.5 feet, approximately 120 feet south of Wilson Road along Line ERT-MEW-13 (borehole BH-19I) to 140 feet near the Wetland Creek (wells MW-16C and MW-20C). The greater alluvium thickness noted within the Wetland area is caused by a depression feature, which possibly might be a localized low, within a buried former river channel, in the surface of the underlying Plattin Limestone.

Figure 4.2 shows the locations for three geologic cross sections across the Site. **Figures 4.3, 4.4** and **4.5** are the geologic cross-sections highlighting the geological sequence from the Site to the downgradient Wetland area, including the potential alluvial channel.

4.1.2 BEDROCK GEOLOGY

The bedrock is encountered at depths varying between 21 feet and 65 feet bgs beneath the Site, to depths between 9.5 feet and 146 feet bgs beneath the Wetland area. The bedrock is composed of weathered, fractured, and solution-enhanced massive limestone.

Bedrock structure was evaluated as part of the RI and included field fracture mapping (especially in nearby quarries), geoprobe investigations, geophysical electrical resistivity tomography (ERT), seismic reflection and refraction assessments, and fracture network analysis using the FRACMAN computer model (Golder Associates, 1998). The bedrock characterization studies were performed to evaluate the distribution and character of fractures and solution-enhanced discontinuities in the Plattin Formation Limestone, evaluate their relevance to local groundwater and transport of COC, assist in the identification of fracture zones, and to develop an improved understanding of the geologic structure at the Site and in the downgradient wetland area.

The bedrock characterization studies indicate that fracturing at the Site is dominated by two principal fracture sets. Both fracture sets are vertical (or near vertical) in dip, and the individual poles for each set are oriented at approximately 76° and 145°, respectively. Horizontal fractures and open bedding planes are common in the upper 15 feet of bedrock, but their frequency and spacing decline rapidly with depth. Below 50 feet of the bedrock surface, horizontal fractures are rare. Fracturing appears to be more intense in the uppermost 31 feet of the bedrock with a fracture intensity of 0.09 ft^2/ft^3. Fracture intensity, which is related to fracture spacing, represents the surface area of fractures to be found in a given volume of rock. In the deeper bedrock, the fracture intensity decreases by an order of magnitude, although the average fracture length (of vertical fractures) increases significantly. Fracture length through the bedrock appears to follow a log-normal distribution.

Based on field fracture mapping of five outcrop locations, including the Lone Star Quarry and East Missouri State Quarry, the bedrock underlying the Site and surrounding areas can be described as existing in the following three zones:

- **Upper weathered zone** – typically 50 feet thick. This zone is characterized by vertical fractures with large apertures, approximately 23 feet apart. These fractures have been enlarged by dissolution, especially at fracture intersections. Fractures with apertures in excess of 3 feet have been observed. The major fracture solution features in this zone are in filled with silty loess deposits. Horizontal bedding plane fracturing is common, especially in the uppermost 10 feet of the bedrock.
- **Intermediate zone** – approximately 115 feet thick. This zone is characterized by persistent vertical fractures spaced 100 to 150 feet apart, with some degree of dissolution-related opening. Fracture apertures are significantly narrower than those in the upper weathered zone and are characterized by varying degrees of calcite and other mineral deposition. Very few horizontal bedding fractures were observed, however this may represent a transport pathway of some significance.
- **Deeper zone** – greater than 260 feet thick. This zone is characterized by occasional discrete vertical fractures more than 150 feet apart. Fractures are narrow and frequently in filled with mineral deposits. Horizontal bedding fractures are rare in this zone, however, this may represent a transport pathway of some significance.

General features of the bedrock structure interpreted from the results of ERT, seismic and geoprobe surveys are presented in **Figure 4.6. Figure 4.6** illustrates an alluvial-filled depression feature extending to at least as deep as 146 feet bgs) is interpreted to exist in the area of monitoring well clusters MW-16, MW-17, MW-20, and MW-21. The deposits that infill this channel or alluvial feature and lie beneath the wetland area, are indicative of a fluvial environment and this feature may indicate a localized low-point within a former fluvial channel. The existing geologic and geophysical data collected in the wetland area can have several interpretations ranging from a closed geologic depression, to a segment of a larger buried channel feature which may, or may not be hydraulically connected to, and part of the Mississippi River Valley system.

Interpreted fracture trends, shown as dashed lines, vary from almost west-east to northwest-southeast, consistent with the fracture model developed from field data. The only fractures displayed are those for which evidence was observed on multiple geophysical profiles and/or inferred from increased geoprobe refusal depths. The location of a suspected fracture or joint feature was displayed along Line MEW-8 and a probable fracture or joint feature was also interpreted along Line MEW-9. The latter fracture zone is aligned with a similar feature as interpreted running through the Property well cluster and well MW-13. The presence of a major vertical fracture zone was confirmed upon advancing monitoring wells MW-15A and MW-15B, based on rock core examination and depth of bedrock, the two main field diagnostic indicators typical for the Site. Major vertical fractures features in the study area are often characterized by significant local depressions in the bedrock surface.

The fracture zone targeted at the location of wells MW-17A/B and indicated along Line ERT-MEW-11 was not found upon investigation. Similarly, the location of a fracture or joint feature displayed along Line MEW-13 was not confirmed upon advancing boreholes BH-19 A through I, which all encountered bedrock at <40 feet bgs. This also indicates the inherent difficulty in identifying vertical fracture zone features using vertical drilling.

4.1.3 HYDROGEOLOGY

The knowledge of groundwater hydrology is based on water levels measured in groundwater monitoring wells and surface water locations during quarterly groundwater monitoring events from 2000 to present and groundwater modeling activities. The majority of onsite wells are completed within the upper weathered bedrock zone with screened depths of less than 60 feet bgs. Monitoring wells MW-5 and MW-6 are completed in the loess, and monitoring wells MW-11 and MW-11A are completed within the intermediate and deep zones. Off-Property monitoring wells MW-16A, MW-16B, MW-16C, MW-17A, MW-18, MW-20A, MW-20B, MW-20C, MW-21A, and MW-21B are completed within the alluvial deposits, and MW-15A, MW-15B, and MW-17B are completed within the limestone.

4.1.3.1 Piezometry and Groundwater Flow

Analysis of groundwater level hydrographs from monitoring wells MW-3 and MW-11 indicate that groundwater within the upper weathered and intermediate zones are in hydraulic continuity. Monitoring well MW-11A, completed in the deep zone, has a different hydrograph response than wells MW-3 and MW-11, which are completed in the upper weathered and intermediate zones, respectively. This suggests that there is limited hydraulic continuity between the intermediate and deep zones.

The groundwater surface at the Property is approximately 40 feet bgs and often occurs within the limestone bedrock. The loess is generally unsaturated, with the exception of perched water (observed in well MW-6) and where the loess deposits occur within fractures in the bedrock below 40 feet bgs.

The majority of flow within the limestone bedrock is interpreted to occur within the fractures in the weathered and intermediate zones. The limestone within the deep zone is described as competent with few fractures. Any fractures that are present within this zone are mostly in filled with mineral deposits and, consequently, there is unlikely to be significant groundwater flow within this zone. The distribution of groundwater heads within the limestone is likely to be strongly influenced by the spatial distribution of fractures, which may give rise to difficulties in interpretation.

Groundwater monitoring from the Study Area indicates that the local hydraulic gradient is southeast toward the Wetland Creek, implying that groundwater flows in this direction. For the shallow alluvial deposits (<25 feet bgs, above a clay layer) the Wetland Creek acts as a groundwater discharge zone as described in the RI Report(Komex, 2005a) and groundwater modeling reports (Komex, 2003a and Komex, 2005b).

The depth to groundwater measured in November 2004 for shallow alluvium wells in the wetland area ranged between 0.47 feet and 3.86 feet bgs. **Figure 4.7** presents the potentiometric surface for wells screened in weathered bedrock (screened shallower than 100 feet bgs), loess, and shallow alluvium deposits (screened shallower than 25 feet bgs) as recorded in November 2004. **Figure 4.8** presents the potentiometric surface for wells screened in the deep alluvial deposits (screened between 50 feet and 150 feet bgs) as recorded in November 2004. Groundwater piezometry within the limestone is relatively complex and is likely influenced by the spatial distribution of fractures.

4.1.3.2 Hydraulic Conductivity

Hydraulic conductivity of the limestone and alluvium deposits has been estimated from slug testing and hydrograph analysis. Slug and packer tests conducted by EarthTech provide an estimate for upper weathered bedrock zone hydraulic conductivity between 2.6×10^{-3} and 0.26 feet/day (feet/d). Slug testing performed by Komex in 2003 gave estimates of bulk equivalent hydraulic conductivity between 0.03 and 2.0 feet/d for the limestone and hydraulic conductivity of 0.89 and 1.8 feet/d for the alluvial deposits beneath the wetlands (Komex, 2003a). The most recent slug testing by Komex (Komex, 2005b) provides estimates of hydraulic conductivity for wells MW-20A, MW-20B, MW-21A, and MW-21B in the alluvial sediments in the wetlands ranging between 0.6 to 28.3 feet/d. Hydrograph analysis performed by Komex in 2003 provided higher estimates of bulk equivalent hydraulic conductivity for the limestone. Estimates using the hydrograph method vary between 10 and 158 feet/d for the upper weathered zone and 8 and 16 feet/d for the intermediate zone. It was concluded, based on data analyzed, that the hydrograph values are on the high end of likely estimates.

4.2 CONTAMINANT SOURCES AND RELEASES

The main source of COPC impacted groundwater at the Site appears to be related to the releases of dielectric fluid associated with onsite drum storage and past recycling operations. Prior to the 1999 soil remedial action, a majority of the surface soils sampled contained PCBs with sporadic detections of volatile organic compounds (VOCs) including methylene chloride, trichloroethene (TCE), 1,1,1-trichloroethane (1,1,1-TCA) and chlorobenzene. Approximately 75 percent of the surface soils (approximately 295,000 square feet or 6.77 acres) on the Property and surrounding areas were found to be impacted with PCBs at concentrations of 10 ppm or greater (USEPA, 1990). PCBs adsorbed onto near-surface soils were transported onto surrounding properties via storm water runoff. Therefore, PCB contamination was located primarily along drainage pathways with concentrations decreasing with increasing distance from the Property.

Results of previous investigations and RI sampling indicated that PCB–impacted soils on the Property were found at depth primarily in two areas, the debris burial area (Area 1) and the transformer storage area (Area 2), as shown on **Figure 4.9**. Area 1 is a rectangular-shaped area, approximately 180 feet by 82 feet, located on the southeast side of the Property between MW-14 and MW-12 and centered on the MW-3/MW-5/MW-11/MW-11A well cluster. A former ditch running northwest to southeast just to the east of the well cluster is believed to be the primary source of PCB contamination in Area 1. Area 2, which has historically been used as a transformer storage area, is an elongated-shaped area located at the center of the Property between wells MW-4 and MW-10. Area 2 is generally defined by detections of TCE and tetrachloroethene (PCE) in monitoring wells MW-4 and MW-10, which have reported the only detectable concentrations of TCE and PCE in groundwater at the Property with the exception of an 8.2 ug/L concentration detected at MW-11 during the November 2004 sampling event. The concentrations of PCE and TCE in soil detected in this localized area are low (Komex, 2005a).

4.3 COPC DISTRIBUTION, FATE AND TRANSPORT

This section describes the distribution of COC in groundwater, probable fate and transport mechanisms of COC, and their migration pathways from the source areas to potential receptors. Contaminant mechanisms which affect COC fate and persistence such as degradation, dispersion and dilution are also discussed.

4.3.1 COPC DISTRIBUTION

COPCs detected in groundwater beneath the Site and surrounding areas consists primarily of PCBs, VOCs and SVOCs related to the former soil source areas. Inorganic compounds were investigated during the initial RI work in the late 1980 and early 1990s and it was determined that the inorganics concentrations at the Site did not indicate the presence of contamination associated with the operations of MEW. (EarthTech 1990, USEPA 1990 ROD). Based on this evaluation and at the direction of the agency, inorganic compounds are not listed as COPCs. The distribution of PCBs, VOCs, and SVOCs detected above laboratory reporting limits (RLs) and MCLs, based on groundwater monitoring conducted in November 2004, is presented in **Figure 4.10.**

4.3.1.1 PCBs

Historically, PCBs (Aroclor 1260) have been detected in unfiltered samples collected from six monitoring wells. These wells include: well MW-3 (at up to 4.7 ug/L, and below the method detection limit in November 2004); well MW-5 (at up to 110 ug/L, 2.9 ug/L in November 2004); well MW-7 (only once at a concentration of 0.35J); well MW-11 (at up to 110 ug/L, below the laboratory reporting limit in November 2004); well MW-11A (at up to 55 ug/L, and below the method detection limit in November 2004); and well MW-12 (at up to 8.3 ug/L, and below the method detection limit in November 2004). PCB results for filtered samples have only been reported for samples collected from well MW-11 over two sampling events (June and September 2000) at concentrations ranging from 2.0 to 4.5 ug/L, after which no result was greater than the laboratory method detection limit. PCBs have not been detected downgradient of the MEW Property since October 2003.

The PCB testing suite included six PCBs, of which only Aroclor-1260 was detected above the MDL, as discussed above. The other five PCBs: Aroclor-1254, Aroclor-1221, Aroclor-1232, Aroclor-1248 and Aroclor-1242 were not detected above their respective MDLs, however, MDLs for these PCBs exceeded the respective screening level and as such, these PCBs were considered as COPCs in the BHHRA (Komex, 2005c).

PCBs tend to strongly adsorb onto particles of clay and organic material, precluding significant migration in the dissolved phase. Typically, PCBs detected in groundwater have been associated with the sediment suspended within the groundwater column, possibly present as sediment at the bottom of each well (and filter pack), and re-suspended during groundwater monitoring activities. This has been confirmed by sampling sediments collected at the bottom of wells MW-5, MW-11, and MW-11A on from September 27 to 29, 2000. All three sediment samples had detected concentrations of PCBs: 5,500 ug/kg in well MW-5; 1,700 ug/kg in well MW-11; and 49,000 ug/kg in well MW-11A. Additionally, these monitoring wells were kept intact during thermal treatment activities. Therefore, some remaining impacted material might reside in close proximity to each of these wells.

Movement of sediment particles from the shallow zone, vertically downward under natural hydraulic gradient, is considered relatively unlikely. This is because sediment particles with adsorbed PCBs would have to migrate their way through the silty-clay sediments, which infill the large vertical fractures in the weathered upper bedrock zone. This winnowing process would require large volumes of percolating water and relatively high flow velocities to mobilize the particles. While it is possible that this occurs in large fractures or weathered zones, it is highly unlikely to occur in the zone represented by well MW-11.

The volume of water required and high flow velocities required to mobilize the PCBs, combined with isotopic evidence (low tritium units [<0.6 TU]) for the presence of older water at depth, point toward the emplacement of COPC at depth via previous drilling practices, especially during lost-circulation events, aggressive pumping during well development, and subsequent aquifer testing (as documented in the Supplemental Hydrogeologic Investigation Report – Earth Tech, 1991). Lost-circulation problems during the Earth Tech (1991) drilling program resulted in significant accumulations of drill-cut sediments in the bottom of boreholes. It is possible that sediment particles with attached PCBs found in voids in well MW-11 were introduced through the drilling and aquifer testing processes in the early 1990s.

Based on the declining trend in PCB concentrations (Komex, 2002b) and the fact that PCBs tend to strongly adsorb onto particles of clay and organic material, it is unlikely that groundwater is a significant dissolved phase transport medium for PCBs (Komex, 2005a).

4.3.1.2 VOCs and SVOCs

The main organic compounds detected in groundwater include: chlorobenzene, 1,2-dichlorobenzene (1,2-DCB), 1,3-dichlorobenzene (1,3-DCB), 1,4-dichlorobenzene (1,4-DCB), 1,2,4-trichlorobenzene (1,2,4-TCB), 1,1,1-TCA, TCE, PCE, 1,1-dichloroethane (1,1-DCA), 1,1-dichloroethene (1,1-DCE), 1,2-dichloroethane (1,2-DCE) and benzene.

Chlorobenzene, 1,2-DCB, 1,3-DCB, 1,4-DCB, 1,2,4-TCB and benzene are all potential components of dielectric fluid, which was recycled from transformers at the Property. Both 1,4-DCB and chlorobenzene are also potential "daughter products" of breakdown of 1,2,4-TCB. Furthermore, 1,1,-DCA and 1,1,-DCE can be derived from the breakdown of 1,1,1-TCA, while 1,2-DCE and 1,1,-DCE can be derived from the breakdown of PCE and TCE. Degradation of chlorinated solvent compounds can occur through both abiotic and biotic mechanisms. Chlorinated solvents may biodegrade both aerobically and anaerobically.

VOCs found above the method detection limits in groundwater samples collected during the November 2004 monitoring event are presented on **Figure 4.10.** In addition, concentrations above the MCLs in November 2004 include:

- chlorobenzene;
- benzene;
- TCE; and
- unfiltered PCBs - Aroclor 1260.

Specific organic COPC are discussed further below.

Of the VOCs detected in groundwater, chlorobenzene has been detected at the highest concentrations and in the most samples. The highest concentration of chlorobenzene was detected in monitoring well MW-12 at a concentration of 3,200 micrograms per liter (ug/L) in November 2004. The previous maximum concentration was 3000 ug/L in December 2002, which had subsequently decreased to 1,500 ug/L in May 2004. Chlorobenzene has also historically been detected in monitoring wells MW-3 and MW-5, located upgradient of well MW-12, at maximum concentrations of 1,600 ug/L and 130 ug/L respectively (390 ug/L and 14 ug/L in November 2004). Chlorobenzene has also been detected on a regular basis in monitoring wells MW-4 (at up to 42 ug/L), MW-11 (at up to 68 ug/L) and MW-14 (at up to 8.9 ug/L). Downgradient of the Property, chlorobenzene has only been detected above the laboratory reporting limit in well MW-7 (at up to 15 ug/L). Chlorobenzene was detected at a J qualified concentration of 2.9J ug/L for a duplicate sample collected from well MW-16C in November 2004. There was no detection above the method detection limit for chlorobenzene in the primary sample collected during the November sampling event from well MW-16C, although chlorobenzene was detected in the duplicate sample for this well at a concentration of 2.9J ug/L.

Benzene was detected in monitoring well MW-12 (at up to 83 ug/L, generally increasing from 26 ug/L since December 2002) and well MW-3 (at up to 17 ug/L) on the Property. Benzene has not been detected above the laboratory reporting limit in samples from groundwater monitoring wells downgradient of the Property. An estimated J qualified detection of 1.7J ug/L was reported for a sample from well MW-16B for the November 2004 groundwater sampling event.

TCE has been detected in monitoring wells MW-4 (at up to 5.2 ug/L), MW-10 (at up to 17 ug/L), MW-11 (at up to 8.9 ug/L) and in WSW-1 (at up to 4.5J ug/L [below reporting limit]) on the

Property. There is historical reference to a maximum on-site detection of TCE at a concentration of 19 ug/L (USEPA, 1990).

TCE has been detected downgradient of the Property in monitoring wells MW-7, MW-16B, and MW-16C at a concentration above the laboratory reporting limit. The November 2004 sampling event detected an estimated TCE concentration of 2.0J ug/L for well MW-15A. Monitoring well MW-7 only had one detection of TCE at a concentration of 9.0 ug/L in March 1990, immediately after well installation. Since then samples from this well have been below detectable levels. Maximum TCE concentrations of 9.9 ug/L and 9.2 ug/L have been detected in samples from monitoring wells MW-16B and MW-16C, respectively. These wells are located in the wetland area screened in alluvial deposits. Estimated TCE values of 2.0J and 1.4J ug/L were observed in groundwater samples from wells MW-15A and MW-14, respectively, during the November 2004 sampling event. In November 2004, TCE was detected at concentrations above the MCL (8.4 ug/L, 7.4 ug/L and 8.2 ug/L for wells MW-16B and MW-16C and MW-11, respectively).

4.3.1.3 COC Trends

Impacted areas at the Property appear to be related to past electrical transformer recycling operations and releases of dielectric fluid. The primary source area (Source Area 1, **Figure 4.9**) of COPC is believed to be a ditch near the on-Site cluster of wells. A secondary source exists (Area 2, **Figure 4.9**) at the center of the Property, which was used as a transformer storage area. Low concentrations of VOCs were also detected in soil in this area.

Organic COPC concentrations above their respective MCL in the Study Area (**Figure 4.10**, as of November 2004) include the following:

- chlorobenzene;
- benzene;
- TCE; and
- unfiltered PCBs - Aroclor 1260.

Chlorobenzene has been detected at its highest concentrations and in the most samples from borehole/well locations on the Property. Chlorobenzene was primarily a component of the dielectric fluid in the recycled transformers. Benzene was detected in monitoring wells MW-12 and MW-3 and is one of only a few examples of a COPC that is increasing in concentration over time at the Site (in well MW-12).

TCE has been detected above its MCL (>5 ug/L) in the wetland area, in wells MW-16B (8.4 ug/L) and MW-16C (7.4 ug/L) installed in alluvial sediments. However, TCE was below reporting limits for all monitoring wells on the Property in November 2004 except well MW-11 (8.2 ug/L), with J-flag concentrations in wells MW-4, MW-10, and former supply well WSW-1. TCE was detected above the laboratory method detection limits in well MW-15A (2.0J ug/L) which may verify migration of some COPC along fractures from the Site towards the alluvium.

There is inconclusive evidence for the source of TCE. Shallow soil samples and low concentrations of TCE in samples from monitoring wells on the Property suggest that there is not a significant source at present. There is not a well-defined near-Site migration pathway for TCE, as there is with chlorobenzene (e.g. chlorobenzene is detected at wells in on-Site wells and downgradient of the Property, at decreasing concentrations from the suspected source area).

PCBs present at depth have exhibited steady declining concentration trends and are now below laboratory reporting levels at all but one location. The presence of COPC at depth, particularly PCBs, has caused historic concern and raised the need to assess migration mechanisms. There are two hypotheses regarding this emplacement: 1) that PCBs were transported associated with sediments during the borehole drilling, well installation, well development and/or testing process; and 2) that PCBs migrated with a solvent (e.g. chlorobenzene) to depth. Given the heterogeneous nature of the bedrock surface, bedrock fractures, and differential infill of fractures and karst solution features, both hypotheses are possible.

Inorganic compounds were investigated during the initial RI work in the late 1980s and early 1990s, and it was determined that the inorganics concentrations at the Site did not indicate the presence of contamination associated with the operations of MEW. (EarthTech 1990, USEPA 1990 ROD). Based on this evaluation and at the direction of the agency, inorganic compounds are not listed as COPCs.

4.3.2 FATE AND TRANSPORT

COC onsite migrate with the direction of groundwater flow. Groundwater flow at the Site occurs primarily through fractures in the Upper Weathered and Intermediate zones. The frequency, orientation, and connectivity of the fractures exert a strong influence on the rate and direction of bedrock groundwater movement. This conceptual model of groundwater flow and COC transport is supported by findings in the RI Report (Komex, 2005a) and Groundwater Modeling Letter Report (2005b) and is summarized below.

1. Recharge of groundwater with the infiltration of rainfall through the surficial deposits across the Site;

2. Occurrence of COC, within the source areas, primarily in loess in-filled fractures in the Upper Weathered Zone and possibly in fractures in the Intermediate Zone, and in loess deposits around well MW-3;
3. Marginal groundwater flow or transport offsite within the surficial deposits due to the limited and probably discontinuous nature of the saturated section below the water table;
4. Relatively rapid groundwater flow and transport offsite as groundwater flows down hydraulic gradient to the southeast, within fractures/fracture zones and bedding planes in the Upper Weathered and Intermediate zones;
5. The limited hydraulic connectivity between the Upper Weathered and Intermediate zones and the Deep Bedrock Zone provides an effective base for the active groundwater transport system;
6. Upward groundwater flow from the fractured bedrock and deep alluvial deposits below the wetland area into the overlying shallow alluvial deposits, which then experiences dilution and dispersion processes;
7. The upward flow of deeper groundwater below the Wetland area may be restricted by a clay aquitard at approximately 25 feet bgs in the alluvium;
8. Potentially slower flow velocities and transport through the porous alluvial deposits than through the bedrock fractures;
9. Some loss of water from the water table in the Wetland area by evapotranspiration during periods of high water table and rapid plant growth;
10. Groundwater discharge to surface water features in the Wetland area (*i.e.* Wetland Creek) via the shallow alluvial deposits; and
11. Limited groundwater flow from the Site to the south of the Wetland area due to the loess-topped limestone ridge to the south of the Wetland area, which gives rise to a similar recharge area with a hydraulic gradient toward the Wetland area (*i.e.* northward).

The main mechanism for concentration reduction in the bedrock is expected to be dilution, as retardation and biodegradation is predicted to be less significant due to the predominance of groundwater flow in the bedrock fractures. Because fracture flow is characterized by a significantly smaller contact surface between the groundwater and the aquifer matrix than occurs with porous flow, COC have less opportunity to sorb onto the aquifer matrix and be retarded. Consequently, it is recognized that retardation and biodegradation in fractured rock occurs to a much lesser extent due to the higher COC transport velocities. However, retardation and biodegradation may be a more dominant factor in the alluvium.

4.4 CURRENT AND POTENTIAL RECEPTORS

A BHHRA was conducted for the Site, which identified current and potential future receptors (Komex, 2005c). The BHHRA evaluated cancer risk and non-cancer hazards posed by Site COPC to these receptors. This section presents a summary of the findings of the BHHRA. The reader is referred to the RI and BHHRA reports (Komex, 2005a and 2005c) for a more detailed discussion of the methods and findings of the assessment.

The BHHRA conceptual exposure model (CEM) identified the following potentially complete exposure pathways:

- Exposure to an adult worker at the Site from the inhalation of COPC vapors that have migrated from the subsurface through the floor into the building;
- Exposure to an off-Site construction worker from direct contact with shallow groundwater in the wetland area; and
- Exposure to an off-Site resident from: (1) inhalation of COPC vapors that have migrated from the subsurface through the floor into the building; (2) ingestion/dermal contact of COPC in groundwater used for water supply; (3) inhalation of COPC arising from use of groundwater; and (4) ingestion and dermal contact with COPC in surface water during recreational use of the creek. Exposure to an off-Site resident not using groundwater at the Site for water supply was also considered; and
- Exposure to possible trespassers from recreational use of the creek (dermal contact and incidental ingestion) may also occur.

A conservative approach was adopted for both the exposure assessment and selection of toxicological parameters. The calculated reasonable maximum exposure (RME) risk factors for organic COPC using these conservative assumptions are presented below:

Receptor	Total Hazard Index (HI) For Organic COPC	Incremental Lifetime Cancer Risk (ILCR) For Organic COPC
Adult worker on MEW Property	0.1	1×10^{-5} to 6×10^{-6}
Adult off-Site construction worker in wetland area	2	5×10^{-7} to 4×10^{-7}
Resident (child and/or adult) on wetland area using impacted groundwater for water supply	124	1×10^{-2}
Resident (child and/or adult) on wetland area with municipal water supply	0.06	2×10^{-6} to 3×10^{-7}
Trespasser	0.003	3×10^{-8}

The calculated RME HI for organic COPC for the adult on-Site worker is 0.1. The RME ILCR for organic COPC for an adult worker ranges from 1×10^{-5} to 6×10^{-6}, depending on the TCE slope factor used. This ILCR is based on a 25-year exposure duration averaged over a 70-year life span.

The calculated RME HI for organic COPC for the adult off-Site construction worker in the wetland area is 2. The RME ILCR for organic COPC for an adult off-Site construction worker ranges from 5×10^{-7} to 4×10^{-7}, depending on the TCE slope factor used. This ILCR is based on a 1-year exposure duration averaged over a 70-year life span.

The EPM has shown that elevated concentrations of organic COPC could exist within the limestone and alluvial deposits beneath the wetland area. A range of risks has been calculated for a future resident using three hypothetical water supply wells located in the wetland area. The highest risk has been predicted for the residential receptor when the drinking water supply well is located within the plume of impacted groundwater. A maximum RME HI of 124 and an ILCR of 1×10^{-2} have been predicted for organic COPC for this scenario using the worst case concentrations predicted by the groundwater model. The ILCR values for the residential receptor are based on a 30-year exposure duration, including 6 years as a child and 24 years as an adult, averaged over a 70-year life span.

The maximum calculated RME HI for organic COPC for a resident that does not use groundwater for water supply or uses groundwater not impacted by organic COPC is 0.06. The calculated ILCR for organic COPC for this scenario is 2×10^{-6} and 3×10^{-7}, depending on the slope factor used.

The calculated RME HI for organic COPC for a trespasser from recreational use of the creek (dermal contact and incidental ingestion) is 0.003. The calculated maximum ILCR for this scenario is 3×10^{-8}. The ILCR values for the trespasser are based on an exposure duration as defined for the off-Site resident.

The following conclusions have been drawn from the risk assessment:

- Risk quantification shows no significant risk to future on-Site workers from indoor vapor intrusion from impacted groundwater beneath the Site.
- Risk quantification shows no significant risk to future off-Property residents from indoor vapor intrusion and recreational use of the wetland creek.
- The assessment shows that there could be a significant risk to future residents living near-site and in the wetland area if they were to use impacted groundwater for water supply.
- The assessment shows that there could be a significant risk to the off-Site worker from incidental ingestion and dermal contact with potentially impacted groundwater.
- The assessment shows that there is no significant risk to future off-Site trespassers from incidental ingestion and dermal contact with potentially impacted groundwater that has discharged to surface water.

5 EVALUATION OF RESTORATION POTENTIAL

This section addresses the restoration potential of the bedrock aquifer, presents a brief discussion of the source control measures that have been performed, and evaluates additional technologies to determine if any could realistically attain drinking water standards for the Site within a reasonable time frame. A detailed discussion of remedial options analysis for bedrock is presented in the FS (Komex, 2005d).

5.1 SOURCE CONTROL MEASURES

Source control measures performed at the Site consisted of the installation of erosion barriers across drainage ditches, during 1989, to minimize the amount of PCB contamination migrating offsite via storm water runoff; and a soil remedial action conducted between June 1999 and July 2000 in accordance with the 1990 ROD and the ESD to the ROD.

The soil remedy selected in the 1990 ROD and amended by the ESD included:

- Excavation and onsite thermal desorption of all soils with PCB concentrations in excess of 10 ppm to a depth of 4 feet, and 100 ppm at depths greater than 4 feet;
- Backfill of excavated areas using treated soils, after analytical tests confirmed that treatment standards were met;
- Restoration and re-vegetation of the Site; and
- Implementation of Institutional Controls (ICs), such as deed restrictions and/or zoning restrictions to limit use of the Site to industrial and commercial purposes.

Approximately 38,000 tons of PCB-impacted soil in excess of 10 ppm were excavated and thermally treated during the soil remedial action to a maximum depth of 27 feet bgs. Confirmation composite samples were collected within 143 50 ft x 50 ft grids, where the average and mean PCB concentrations were 1.6 ppm and 0.7 ppm, respectively. After treatment and analyses to confirm the treatment standards had been met, treated soil was used to backfill excavated areas onsite. The entire area was capped with contaminant-free soil and the upper foot of cap was enriched to support vegetation. To date, no ICs have been placed on the areas addressed by the soil remedial action. The soil remedy was completed with the acceptance of the Soil Remedial Action Report during September 2000.

By meeting the target cleanup goals for soil, the remedial action achieved the remedial action objectives established for the source control component in the 1990 ROD. Although no ICs have been implemented to date, the need for deed restrictions for soil contamination no longer exists, because no PCB concentrations at depth exceed 100 ppm.

5.2 ANALYSIS OF REMEDIAL ACTION PERFORMANCE AND RESTORATION TIMEFRAME

5.2.1 BACKGROUND

The groundwater remedial alternative stipulated in the 1990 ROD was the collection of groundwater utilizing an extraction well network, temporary storage, followed by removal of volatile organics utilizing an air stripper with gas phase carbon adsorption from the air stream.

5.2.2 IDENTIFICATION OF REMEDIAL OPTIONS

5.2.2.1 Basis of Evaluation

A detailed discussion of the remedial technologies and process options considered for remediation of COC in bedrock at the Site is provided in the FS (Komex, 2005d). This process followed USEPA (USEPA 1988a) guidance. Remedial technologies and process options retained from the initial screening step were then evaluated in more detail to further focus the development of remedial action alternatives. This step involved evaluating process options within the same technology type based on the criteria of effectiveness, implementability, and cost. The evaluation of process options for the COC impacted fractured bedrock presented in the FS is summarized here for completeness. The processes retained from this evaluation were then used to assemble remedial action alternatives for the proposed Bedrock TI zone.

The main criteria in USEPA guidance (USEPA, 1988a) are effectiveness, implementability, and relative cost, defined as:

Effectiveness - This criterion focuses on the potential effectiveness of process options in handling the estimated areas or volumes of media and meeting the RAOs; the potential impacts to human health and the environment during the construction and implementation phase; and how proven and reliable the process is with respect to the COC and conditions at the Site.

Implementability - This criterion encompasses both the technical and administrative feasibility of implementing a process. Technical implementability was used in the initial screening of technology types and process options to eliminate those that are clearly ineffective or impractical at the Site.

Cost - This criterion plays a limited role in the screening of process options. Relative capital and operation and maintenance (O&M) costs are used rather than detailed estimates. The cost analysis is based on engineering judgment and each process is evaluated as high, medium, or low cost relative to other processes in the same technology type.

Consistent with USEPA guidance (USEPA, 1988a), the following evaluation is focused on effectiveness factors, with less effort directed at the implementability and cost evaluation. The remedial technologies and process options retained are then used to assemble remedial action alternatives.

The FS identified seven general response actions (GRAs) after initial screening:

- No Action;
- Limited Action;
- Containment;
- Collection;
- Ex-situ treatment;
- Discharge; and
- In-situ treatment.

Of these, the five most relevant to the TI assessment are summarized below. The ex-situ treatment and water discharge options are not discussed herein, since the groundwater collection system limitations are the relevant issue for TI. More detail on the evaluations can be found in the FS report (Komex, 2005d).

5.2.2.2 No Action

The GRA termed "No Action" was carried forward for evaluation because it provided a baseline to which other GRAs and their associated remedial technologies could be compared. "No Action" entails no activities to contain or remediate COC at the Site, provides no treatment for COC, and provides no legal or administrative protection of human health or the environment beyond cleanup criteria. "No Action" assumes that physical conditions at the Site remain unchanged and does not preclude that natural attenuation, including advection, dilution, and dispersion, will act to reduce the concentration of COC in groundwater. However, verification that natural attenuation processes are operating would not take place.

Effectiveness. "No Action" generally would not achieve the RAOs for the Site. Groundwater would continue to exhibit COC concentrations in excess of TCLs, and no ICs would be in-place to limit exposure to contaminated groundwater and restrict future use of impacted groundwater.

Implementability. There are no implementability limitations associated with the "No Action" GRA.

Cost. There are no capital costs or O&M costs associated with the "No Action" GRA.

Conclusion. The "No Action" GRA was retained as required by CERCLA and the NCP as a baseline with which to compare other remedial alternatives.

5.2.2.3 Limited Action Alternative

The Limited Action remedial technologies and process options that are potentially applicable to COC impacted groundwater within the fractured bedrock are discussed further below:

Remedial Technology	Process Option
ICs	Land and Resource Use Restriction
Wellhead Treatment	Future Water Supply Wellhead Treatment Systems
Long-Term Monitoring	Groundwater Monitoring

5.2.2.3.1 Institutional Controls

ICs are non-engineering measures used to manage site risks by limiting potential exposure to COC and/or by protecting and ensuring the integrity of the remedy. Examples of ICs cited in the NCP, include land and resource use restrictions (e.g., water), well-drilling prohibitions, building permits, well use advisories and deed notices. ICs, such as land use and access restriction manage human health risk by limiting the potential for exposure from ingestion and dermal contact with groundwater and inhalation of VOCs. ICs could also include health and safety policies and procedures to limit exposure to groundwater COC during construction activities.

Effectiveness. ICs do not meet all the Site RAOs as they do nothing to reduce the mobility, toxicity, or volume of COC at the Site, although they are effective for reducing risk to human health. The effectiveness of ICs depends on the mechanisms used and the durability of the IC.

Land and resource use restrictions are considered effective. No additional risks to human health and the environment would directly result from the imposition of ICs.

Implementability. ICs could be implemented as a stand-alone remedy or in combination with other alternatives. ICs that are developed as part of an alternative may require administrative activity and legal action on the part of the Property owner, the State and/or local authorities.

Cost. Capital and O&M costs for institutional controls are considered low compared to other Limited Action process options.

Conclusion. Although ICs acting alone do not adequately address the groundwater RAOs for the Site, they are effective for reducing risk to human health.

5.2.2.3.2 Wellhead Treatment Systems

This option involves the installation of wellhead treatment systems at any existing potable water supply well in the event that one becomes impacted by COC, or new potable water supply wells are installed where extracted groundwater could be reasonably expected to have COC concentrations greater than TCLs.. The treatment system is termed "wellhead" because it is installed at the wellhead of the water supply well. Air strippers and carbon adsorption units, either alone or in series, are the most common types of wellhead treatment systems for VOCs and SVOCs. A suitable financial instrument could be put in place to ensure that if such impacts occur at an existing well, or a future well drilled for water supply within the Bedrock TI zone, that a well-head treatment system could be put in place to protect the users.

Effectiveness. Wellhead treatment is an effective method to reduce risks to human health through exposure to impacted groundwater. Typically, however, drinking water supply wells are not used to extract groundwater for the purpose of containing or remediating a COC groundwater plume.

Implementability. Wellhead treatment is readily implemented using conventional, commercially available equipment.

Cost. The capital and O&M costs for wellhead treatment are considered moderate, although this depends on the number of wellhead treatment systems required.

Conclusion. Although wellhead treatment acting alone does not adequately address the Site RAOs, it does reduce risk to human health. This option is retained since groundwater COC are expected to persist at levels above TCL concentrations for a number of years, even under active remediation scenarios, and this option could be an important component of several remedial alternatives.

5.2.2.3.3 Groundwater Monitoring

Groundwater monitoring would be used to evaluate changes in groundwater quality conditions resulting from leaching, migration, or natural attenuation processes. Monitoring can also be used to assess the effectiveness of groundwater remediation measures.

<u>Effectiveness</u>. Groundwater monitoring is not effective for reducing risk to human health and is not effective in attaining RAOs for groundwater. However, this option is an effective tool for assessing the migration of COC in groundwater, and the continuing need for other measures.

<u>Implementability</u>. A long-term groundwater monitoring program could be readily implemented using conventional techniques and procedures previously used at the Site.

<u>Cost</u>. The capital and O&M costs for long-term groundwater monitoring are considered to be low and moderate, respectively, compared to other technologies.

<u>Conclusion</u>. Although groundwater monitoring does not address RAOs for the Site, this option could be used to assess the migration of COC in groundwater and as a measure of the effectiveness of other components of a remedial alternative, particularly as part of annual and five-year Site reviews.

5.2.2.4 Containment Alternative

Containment technologies refer to methods, which are intended to limit/prevent the mobilization and migration of COC, as well as measures which limit/prevent direct human and ecological contact with COC. Containment may not remove COC, reduce their concentrations, or actively alter their chemical state. Containment measures for impacted groundwater typically include low-permeability capping, hydraulic gradient controls and vertical barriers. COC removal (as a consequence of a gradient control system) may gradually achieve TCLs within the contained area.

Low-permeability capping is a groundwater containment technology intended to form a horizontal infiltration/recharge barrier, which also limits leaching and migration of COC from soil into groundwater. Typically, when used alone, low-permeability caps only reduce leaching of COC from vadose zone soils (i.e. by reducing/eliminating infiltration). COC located at/or below the water table (i.e. smear zone), would continue to leach to groundwater. Of various capping systems assessed in the FS, the clay/soil cap process option was selected to represent the low-permeability capping technology because it is considered equally effective when compared to the other process options, and its costs are lower. The clay/soil capping process option is evaluated below.

5.2.2.4.1 Clay/Soil Cap

This option would involve the placement of a clay layer over COC-impacted soils to limit the infiltration of precipitation and associated leaching of residual soil COC into groundwater. In general, this and other low-permeability caps only reduce leaching of COC from vadose zone soils. COC at/or below the water table (i.e. smear zone) would continue to leach to groundwater. The clay cap would be covered with topsoil and vegetation to protect the clay from weathering and erosion.

Effectiveness. The locations of residual COC in soil and vadose zone have been tentatively identified based upon sampling. Residual COC may be located at depth and in isolated zones, separated by areas without residual COC. The clay/soil cap will therefore have limited effectiveness if the locations of the residual COC are not covered. The clay/soil cap is only effective for COC in the vadose zone. Capping will not reduce residual soil or groundwater COC concentrations. In addition, the long-term effectiveness of a clay/soil cap may be reduced by weather-related and biological-related deterioration, and hence would require routine inspection and maintenance. This process option does not achieve Site RAOs, and in order to be effective, must be combined with other containment remedial technologies.

Implementability. The construction of a clay/soil cap is considered readily implementable. However, the implementation and future enforcement of ICs, which would be required in conjunction with this option to prevent human excavation or penetration of the cap is potentially more challenging.

Cost. The capital and O&M costs for a clay/soil cap are considered moderate compared to the other low-permeability capping options previously screened and eliminated.

Conclusion. Although a clay/soil cap would limit the infiltration of precipitation and associated leaching of residual soil COC into groundwater without a vertical barrier (which was eliminated in the initial screening step due to technical feasibility), COC at or below the water table would continue to leach to groundwater. Therefore, the clay/soil cap process option and containment as a GRA was eliminated from further consideration due to limited effectiveness.

5.2.2.5 Collection Alternative

Groundwater collection refers to technologies that are used to collect, withdraw, or extract COC-impacted groundwater by passive or active means. Collection physically removes COC-impacted groundwater from the subsurface and is typically coupled with ex-situ treatment processes to remove the COC from the groundwater before it is discharged to either a surface water, groundwater, or is reused. A combination of collection, ex-situ treatment and discharge, also described as pump and treat, is used to provide hydraulic containment and to reduce groundwater COC. Ex-situ treatment and discharge technologies for groundwater were evaluated in the FS (Komex, 2005d).

The following groundwater collection process options were retained in the screening step for COC-impacted groundwater within the fractured bedrock:

Remedial Technology	Process Option
Extraction (Groundwater Pumping)	Vertical-Drilled Extraction Wells
	Horizontal/Angled-Drilled Wells
Dual-Phase Extraction	Dual-Phase Extraction

Given the complex nature of the discrete fracturing of the bedrock, and the importance of vertical fractures in controlling and dominating groundwater flow and COC transport within bedrock, angled-drilled extraction wells are judged to have an advantage over vertical wells in terms of the likelihood of intersecting target vertical fracture zones. As such, angled wells have been selected to represent the groundwater collection technology. Dual-phase extraction was not considered to best represent groundwater collection as it is typically more expensive than groundwater pumping and is not considered to offer a higher level of treatment. The angled-drilled extraction well process option is evaluated below.

5.2.2.5.1 Angle-Drilled Extraction Wells

An angle-drilled extraction well system consists of a series of wells, which are installed at an orientation normal to the strike of the target fractures. Wells are installed at an angle to the ground surface (often at about 45 degrees, but may vary depending on circumstances). Installed wells are completed across target fracture zones, and equipped with pumps (typically submersible) to capture impacted groundwater. Angle-drilled extraction wells, when compared to other groundwater collection options (such as vertical wells) are typically more expensive to implement as they require specialized drilling equipment, and installation can be problematic.

At this Site, angle-drilled wells offer a higher probability of success in intercepting target vertical fracture zones when compared to more conventional vertically drilled wells.

Effectiveness. Given that groundwater migrates through fractures in the bedrock, and the distribution of COC in groundwater is controlled by the presence of mainly vertical fractures (Komex, 2005a), the effectiveness of this remedial technology will depend upon the technology's ability to extract COC impacted groundwater. Ability to extract COC-impacted groundwater depends on being able to identify major vertical fractures, to determine which of the many fractures within the bedrock mass actually contain appreciable mass of COC, and then to complete wells which adequately intersect those fractures.

During site characterization, attempts were made to identify individual major vertical fractures responsible for COC migration. Well MW-12 was successful in intersecting such a fracture. COC concentrations above the laboratory RL were measured in samples from well MW-12. However, well MW-13, completed in what appeared to be a similar, parallel vertical fracture approximately 35 feet to the east of well MW-12, has not yielded COC concentrations above their respective RLs. Similarly, samples collected from wells installed downgradient in the fractured bedrock, in the presumed direction of COC transport, did not detect COC at concentrations predicted by EPM modeling (see Komex, 2005b). Although the EPM model can reasonably predict COPC concentrations in a simulated fracture and model results are valid for scales of evaluation that are likely to include one or more fractures, the exact occurrence, location and geometry of fractures in the field are not known. Therefore, model results can be used to assess worst-case risk to hypothetical receptors (by wells modeled as being installed in simulated fractures); however, the results can not be used at the scale necessary to precisely locate wells for either remediation or water supply purposes.

If all the fractures, which are actually transporting COC off Property, cannot be identified or located exactly, then the effectiveness of the process option to collect COC-impacted groundwater from the fractured bedrock is considered negligible. Furthermore, due to the complex fracture network configuration and the difficulty in detecting which fractures actually contain COC and which do not, active pumping of groundwater via angled-drilled wells also has the significant risk of redistributing COC within un-impacted fractures and causing further spreading of the plume.

For the reasons stated above, there is a high likelihood that such extraction systems potentially would result in the pumping of large volumes of previously un-impacted groundwater through the impacted bedrock zone. Combined with the possible redistribution of COC into previously un-impacted fracture networks, triggered by a significant change in hydraulic regime, it is unlikely that Site ARARs could be met, irrespective of the length of time over which pumping was carried out.

Angle-drilled extraction wells are not effective for reducing risk to human health as they do not restrict use of the groundwater and therefore, on their own do not achieve all the Site RAOs.

Implementability. An angle-drilled extraction well system is considered difficult to implement at the Site, as it requires specialized drilling equipment and techniques. To ensure intersection of identified target fracture zones, it is foreseeable that a large number of wells would be required. Uncertainties regarding the location of all the fractures actually transporting COC offsite potentially further increase the number of required wells. The implementation of a large bedrock drilling program using angle-drilled wells, targeting an uncertain number of fracture zones, in uncertain locations, is considered difficult and practically infeasible.

Cost. The capital and O&M costs for angle-drilled extraction wells are considered high and moderate, respectively, when compared to other groundwater collection technologies screened out earlier.

Conclusion. Angle-drilled extraction wells in fractured bedrock have limited effectiveness and may cause the spread of contamination, are considered very difficult to implement and are likely to be very costly, requiring specialized equipment. This process option, based on effectiveness and implementability, is eliminated as a potential component of remedial action alternatives that are focused on COC impacted groundwater within the fractured bedrock, regardless of the ex-situ treatment and discharge technologies coupled with it.

5.2.2.6 In-Situ Treatment Alternative

The "In-situ Treatment" alternative refers to technologies and associated process options, which are used to treat contaminated groundwater in place without pumping to a surface treatment system. The main advantages of in-situ treatment are the elimination of groundwater extraction and the subsequent need for discharge, the attendant costs, treatment residuals handling/disposal, safety, and permitting/ARAR compliance issues. Disadvantages of in-situ treatment compared to an ex-situ treatment system include, uncertainties regarding treatment uniformity, delivery and effectiveness due to an inability to directly monitor and control the treatment process (FRTR, 1997).

Evaluation of in-situ treatment process options, including air sparging, enhanced-bioremediation, and natural attenuation, revealed several treatment limitations imposed by the fractured bedrock environment at the Site. First, despite extensive characterization at the Site, the true connectivity of fractures responsible for COC transport remains unknown, therefore accessibility of introduced agents to COC cannot be reliably predicted. Second, in some fracture zones, the hydraulic conductivity may vary drastically from one area to another, complicating remedial system design. Third, fractures typically create preferential pathways for fluid flow that reduce the ability of in-situ remediation systems to contact dispersed contaminants. Sparge systems designed to strip volatile contaminants from groundwater are largely ineffective in fractured bedrock because the injected air/oxygen finds preferential fracture pathways, restricting influence to the remaining plume area. This limitation also extends to sparge-type systems that are implemented to provide dissolved oxygen for biological contamination degradation, as these systems are simply unable to transfer dissolved oxygen to the bulk of the plume area. This same limitation also applies to oxygen release chemicals. The complex geological setting at the Site also precludes adequate monitoring of in-situ treatment performance. In addition, injection of air, oxygen, nutrients, oxidants, or reductants has the potential to cause unpredictable redistribution of COC and the potential to redistribute COC within un-impacted fractures and cause further spreading of the plume. The inherent limitations and difficulties in implementing in-situ methods are similar to the ones discussed above for groundwater collection systems evaluation.

In-situ process options, with the exception of monitored natural attenuation (MNA), were eliminated in the screening step for COC impacted groundwater within the fractured bedrock. The evaluation of MNA is discussed below.

5.2.2.6.1 Monitored Natural Attenuation

The USEPA guidance document "Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, And Underground Storage Tank Sites" (OSWER Directive 9200.4-17) (USEPA, 1997) clarifies the USEPAs policy regarding the use of MNA at fractured bedrock sites. The OSWER directive states the following:

"In some complex geological systems, technological limitations may preclude adequate monitoring of a natural attenuation remedy to ensure with a high degree of certainty that potential receptors will not be impacted. This situation typically occurs in many karstic, structured, and/or fractured rock aquifers, where groundwater moves preferentially through discrete channels. The direction of groundwater flow through such heterogeneous (and often anisotropic) materials cannot be predicted directly from the hydraulic gradient, and existing techniques may not be capable of identifying the channels that carry contaminated groundwater through the subsurface. Monitored natural attenuation will not generally be appropriate where site complexities preclude adequate monitoring."

Given USEPA policy regarding the use of MNA at fractured bedrock sites, MNA as a process option applicable to COC-impacted groundwater within the fractured bedrock was eliminated on the basis of technical infeasibility to monitor natural attenuation processes with a high degree of certainty.

5.2.3 SELECTED REMEDIAL ALTERNATIVE PERFORMANCE EFFECTIVENESS EVALUATION

5.2.3.1 Overview

Following the identification, screening, and detailed evaluation steps carried out in the FS and summarized above, the following remedial technologies and process options were retained as possible components of a remedial action alternative for COC-impacted groundwater within the fractured bedrock:

GRA	Remedial Technology	Process Option
FB-1: No Action	Not Applicable	Not Applicable
FB-2: Limited Action	ICs	Land and Resource Use Restrictions
	Wellhead Treatment	Future Water Supply Wellhead Treatment Systems
	Long-Term Monitoring	Groundwater Monitoring

As discussed above, active remedial technologies, such as in-situ or ex-situ treatment, were eliminated as part of the identification, screening, and detailed evaluation steps. The major factors contributing to the elimination of other alternatives were:

- Inherent limitations in identifying specific fractures and fracture-zones where COC exist within the karst bedrock mass. Without predictable access to COC, in-situ alternatives become problematic to implement, and groundwater collection alternatives are uncertain;

- Technical limitations in locating with any degree of certainty the major fracture and karst features, which act as the main conduits for COC migration. As above, without some degree of predictability of where key fractures or karst features are, in-situ and collection treatment systems are extremely difficult to implement effectively;

- Engineering limitations in installing angled wells to intercept the key fracture and karst features. Angled wells are advantageous in being able to intercept more predictably vertical features, but are much more problematic and expensive to drill and install properly.

- The existence of multiple fracture networks and karst features in partial hydraulic connection at certain points within the system can readily lead to an unpredictable redistribution of COC if the prevailing natural groundwater regime is altered significantly, as it would be with either groundwater pumping or significant injection of in-situ treatment agents. Pumping or large-scale injection could trigger unpredictable spreading of COC and introduction of COC into fracture networks and karst features which to date have not been impacted

- Difficulty in adequately monitoring COC within this type of highly heterogeneous system renders measurement of remedial performance, regardless of the system installed, particularly challenging. For this reason, USEPA does not consider MNA to be a viable technology in fractured rock.

- Due to the technical considerations discussed above, remedies implemented in fractured bedrock may exacerbate the migration of contamination, the costs for implementing active remedies in bedrock at the Site would be high, and would also be difficult to predict with any certainty, without any assurance that RAOs/ARARS would be reached.

- Due to the technical and engineering limitations discussed above, the amount of time required to reach ARARs cannot be reliably determined, however this period is expected to be greater than 30 years and could be greater than 100 years. Due to the limitation in monitoring of effectiveness, determining when remedial goals have been met would also be problematic.

5.2.3.2 Detailed Analysis of Alternatives

This section summarizes the detailed evaluation of the two retained remedial action alternatives for bedrock, following the process set out by the NCP under Section 300.430 (e) 9 (iii) and further described in the USEPA guidance document (USEPA, 1988a). The NCP process identifies nine evaluation criteria, which provide the basis for conducting the detailed analysis of remedial alternatives and for subsequently selecting an appropriate remedial action alternative. The nine evaluation criteria are:

- Overall Protection of Human Health and the Environment;
- Compliance with ARARs;
- Long-term Effectiveness and Permanence;

- Reduction of Toxicity, Mobility, and/or Volume through Treatment;
- Short-term Effectiveness;
- Implementability;
- Cost;
- State Acceptance; and
- Community Acceptance.

The first two criteria listed above (i.e. overall protection of human health and the environment, and compliance with ARARs) are "threshold" criteria in that they relate directly to statutory findings that must ultimately be made in the decision document, and therefore they must be satisfied in order for an alternative to be selected. The next five criteria represent the primary "balancing" criteria upon which the comparative analysis of alternatives is based. The final two evaluation criteria: State acceptance and community acceptance, represent modifying criteria, which will be considered in the comparative analysis of alternatives and fully assessed following public comment on the FS Report and the proposed plan.

For completeness, a summary of the analysis of the two retained alternatives is provided below. More detailed descriptions of these criteria and their application to the alternatives is provided in the FS report (Komex, 2005d).

5.2.3.3 Alternative FB-1: No Action

5.2.3.3.1 Alternative Summary

Alternative FB-1, the No Action alternative, is intended to provide a baseline against which other alternatives can be compared, as required by the NCP under Section 300.68.

5.2.3.3.2 Overall Protection of Human Health and the Environment

Alternative FB-1 is not protective of human health because no action is proposed and the risks posed by the Site under current conditions, as described in the BHHRA (Komex, 2005c), would continue to be present under this alternative.

5.2.3.3.3 Compliance with ARARs

Alternative FB-1 does not address groundwater contamination, and hence, wherever COC currently exceed ARARs, this alternative is not compliant with ARARs.

5.2.3.3.4 Long-Term Effectiveness and Permanence

Existing residual groundwater contamination within the proposed Bedrock TI zone poses unacceptable human health risks under possible future groundwater use scenarios. Under the "No Action" alternative, the risks would remain unacceptable over the long term. Additional unacceptable risks could occur if incompatible land uses and unanticipated groundwater use as a drinking water supply were allowed.

5.2.3.3.5 Reduction of Toxicity, Mobility, or Volume Through Treatment

Although natural attenuation processes could act to reduce the toxicity or volume of Site groundwater COC, no work has yet been undertaken at the Site to assess the potential for MNA. In addition, MNA in this type of bedrock environment is not considered practicable (see above). Alternative FB-1 does not propose implementation of a process option to verify this.

5.2.3.3.6 Short-Term Effectiveness

There are no additional risks to the community and environment posed by Alternative FB-1 because no significant remedial activities are planned. However, RAOs would not be met under this alternative.

5.2.3.3.7 Implementability

Alternative FB-1 is readily implemented because no actions would need to be taken.

5.2.3.3.8 Cost

Costs associated with Alternative FB-1 are discussed in detail in **Section 6.0.**

5.2.3.4 Alternative FB-2: Institutional Controls/Wellhead Treatment/ Long Term Monitoring

5.2.3.4.1 Alternative Summary

Alternative FB-2 relies on ICs, future wellhead treatment and groundwater monitoring. Under this alternative, ICs would be established to prohibit/restrict certain Site uses and prohibit the use of untreated contaminated groundwater. ICs would be augmented by wellhead treatment at existing potable wells, in the event they become impacted and/or new potable water supply wells are installed in the future. The combination of ICs and wellhead treatment would prevent the use of groundwater containing COC. Groundwater monitoring will be conducted.

5.2.3.4.2 Overall Protection of Human Health and the Environment

Implementing Alternative FB-2 at the Site would protect human health over the long term through a combination of ICs and future wellhead treatment. ICs would limit certain Site and near-Site uses and prohibit the use of untreated COC impacted groundwater for any purpose. In the case where an existing potable well should become impacted, or a new potable water supply well is installed where it could extract groundwater that could reasonably be expected to have COC at concentrations that exceed the TCLs, a wellhead treatment system would be constructed.

5.2.3.4.3 Compliance with ARARs

Alternative FB-2 will not be compliant with ARARs that regulate drinking water.

5.2.3.4.4 Long-Term Effectiveness and Permanence

Alternative FB-2 does not act to reduce the toxicity, and/or mass of COC in groundwater. Residual human health risks from COC in groundwater would remain for an unknown period and ICs would be required for an indefinite period to ensure protectiveness. ICs are intended to limit exposure to COC impacted groundwater. These controls coupled with wellhead treatment, are expected to prohibit ingestion of or contact with untreated groundwater for any use over the long term. As such this alternative will manage the risk posed by the COC impacted groundwater Alternative FB-2 is considered effective over the long term.

5.2.3.4.5 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative FB-2 will not act to reduce the toxicity mass or mobility of COC in groundwater. Therefore, Alternative FB-2 is not considered effective at satisfying this criterion.

5.2.3.4.6 Short-Term Effectiveness

Alternative FB-2 requires no aboveground treatment (beyond future wellhead treatment), thus minimizing direct worker contact with groundwater. No intrusive activities would be necessary because the groundwater wells are already installed. Long-term groundwater monitoring has minimal impact on workers responsible for periodic groundwater sampling and any risks to workers can be controlled and mitigated by implementation of proper health and safety measures in accordance with OSHA 1910.120. COC concentrations in groundwater are anticipated to exceed TCLs for a time scale of greater than 30 years. FB-2 is considered to present a minimal short-term effect.

5.2.3.4.7 Implementability

Alternative FB-2 is technically and administratively implementable at the Site. ICs that are developed as part of these alternatives may require administrative and legal action. ICs can be implemented without significant delays.

5.2.3.4.8 Cost

Costs associated with FB-2 are discussed in detail in **Section 6.0.**

6 PROPOSED BEDROCK REMEDIAL ALTERNATIVE COST ESTIMATES

This section describes the costs for the range of proposed remedial alternatives, as described in detail in the groundwater FS for the fractured bedrock (Komex, 2005d), and summarized in section 5 of this report. These alternatives are:

- FB-1: No Action; and
- FB-2: Institutional Controls/Wellhead Treatment/Long-Term Monitoring.

6.1 NO ACTION ALTERNATIVE (FB-1)

Under the "No Action" alternative, no action would be taken to alter conditions at the Site, therefore there are no costs associated with the "No Action" alternative.

6.2 INSTITUTIONAL CONTROLS/WELLHEAD TREATMENT/LONG-TERM MONITORING ALTERNATIVE (FB-2)

A range of costs has been prepared to reflect an accuracy of +50% to -30% of the estimated cost in accordance with USEPA guidance (USEPA, 1988a).

There is no capital cost associated with Alternative FB-2. Annual costs are estimated at $155,719 (2nd year) and $75,074 (4th year) for FB-2. The cumulative net present value of these costs over 5, 10, 15, 20, 25 and 30-year periods, including periodic costs (e.g., five-year reviews), assuming an inflation rate of 3.0% and an initial discount rate of 5.0% for the first 15 years, then 4.0% thereafter, are summarized below.

FB-2

Operational Period	Cumulative Net Present Value (-30%)	Cumulative Net Present Value	Cumulative Net Present Value (+50%)
5-Years	$443,873	$634,105	$951,157
10-Years	$683,556	$976,509	$1,464,763
15-Years	$901,265	$1,287,522	$1,931,283
20-Years	$1,136,397	$1,623,425	$2,435,137
25-Years	$1,360,440	$1,943,486	$2,915,229
30-Years	$1,573,917	$2,248,453	$3,372,679

It should be noted that Alternative FB-2 costs are for the fractured bedrock only, and do not include costs for an associated monitoring program that might be undertaken simultaneously in the alluvial deposits, as is discussed in the FS (Komex, 2005d).

7 PROTECTIVENESS OF PROPOSED REMEDIAL ALTERNATIVE

7.1 DETAILED DESCRIPTION OF INSTITUTIONAL CONTROLS/WELLHEAD TREATMENT/LONG-TERM MONITORING ALTERNATIVE FB-2

The institutional controls/wellhead treatment/long-term monitoring alternative (FB-2) as described above (and in the FS Report [Komex, 2005d]) is the proposed alternative remedial strategy for fractured bedrock groundwater if a TI waiver is granted. This alternative is proposed within the context of a possible determination by the USEPA that it is technically impracticable to restore groundwater within the fractured bedrock within a reasonable time frame (within 30 years).

Alternative FB-2 incorporates ICs, future wellhead treatment, and groundwater monitoring. The specific components of Alternative FB-2 are as follows:

7.1.1 INSTITUTIONAL CONTROLS

Institutional controls will be implemented in layers as appropriate to enhance the protectiveness of the remedy. The primary form of institutional control for the Property is expected to be a proprietary control, specifically a restrictive covenant and grant of access. This form of proprietary control was selected as it is effective as an informational device and creates a readily enforceable legal property interest. For areas where COC are present off the Property, this proprietary control may also be effective; however, a special area designation or other techniques may also be appropriate.

The imposition of a restrictive covenant and grant of access on the Property will be sought. The grantee of this restrictive covenant will have the right of access and the authority to enforce the restrictive covenant. The EPA may be named as a third-party, or intended, beneficiary in this instrument so that EPA may also have the ability to enforce the terms of the restrictive covenant and grant of access.

This restrictive covenant and grant of access will be patterned on either the: 1) Model Restrictive Covenant and Grant of Access found in the MDNR CALM Appendix E, Attachment E1; 2) the proposed Model Declaration of Restrictive Covenant and Grant of Access which is anticipated to be located in the MDNR Long-term Stewardship for Risk-based Corrective Action Sites, Appendix J, Technical Guidance; or 3) other appropriate instruments.

The objectives of imposing a restrictive covenant and grant of access on this Site are to eliminate or minimize exposures to contamination remaining at the Site and limit the possibility of the spread of contamination. These objectives will be achieved by use of the restrictive covenant and grant of access as it will: 1) provide notice; 2) limit use; and 3) provide for all required access.

Specifically, the restrictive covenant and easement will achieve this by:

- providing notice to prospective purchasers and occupants that there are contaminants in the groundwater.
- ensuring that future owners are aware of engineered controls (if any) put into place as part of this remedial action.
- prohibiting residential, commercial and industrial uses, except those uses which would be consistent with the remedial action.
- prohibiting or restricting the placement of groundwater wells.
- prohibiting other ground penetrating activities which may result in the creation of a hydraulic conduit between water bearing zones.
- providing access to USEPA and the State of Missouri for verifying land use.
- prescribing actions that must be taken to install and/or maintain engineered controls (if applicable).
- providing access to USEPA and the State of Missouri for sampling and the maintenance of engineered controls (if applicable).

In addition to the above proprietary control, MDNR Geological Survey & Resource Assessment Division may designate the impacted areas associated with the MEW Site as a "special area" as provided for in the Well Driller's Act, RSMo 256.606. Special areas are geographic regions that are subject to stringent well-drilling requirements due to special circumstances, such as the presence of groundwater contamination. Such a designation would require rulemaking, and, if established, would require all well installation contractors to follow new drilling standards for well construction in the contaminated area.

Other ICs may include but are not limited to: ordinances; inspection regimes; property notices; and public information.

7.1.2 WELLHEAD TREATMENT SYSTEMS

Wellhead treatment systems could be installed and maintained for any existing potable water supply well in the event that one becomes impacted by COC, or new potable water supply wells are installed where extracted groundwater could be reasonably expected to have COC concentrations greater than TCLs. To address an unconfirmed potential future need, the installation and maintenance of a wellhead treatment system at one water supply well in the future is contemplated under this alternative. Wellhead treatment consists of treatment systems, such as activated carbon/air strippers, to remove VOCs from groundwater pumped for potable use. Ongoing maintenance of wellhead treatment systems would include periodic change out of spent carbon, as well as, other adjustments/repairs necessary to maintain proper function of the systems.

Assuming that a future wellhead treatment system is necessary where extracted groundwater could be reasonably expected to have COC concentrations greater than TCLs, the process for well installation and operation would be the subject of a detailed design and the formation of an operation and maintenance report. A suitable financial instrument would be put in place to ensure that if such impacts occur at an existing well, or a future well were drilled for water supply within the Bedrock TI zone, that a well-head treatment system could be put in place to protect the users.

7.1.3 GROUNDWATER MONITORING

Groundwater monitoring could involve sampling and laboratory analysis of COC impacted groundwater from the 14 existing monitoring wells installed within the bedrock (**Figure 1.2**). The subset of 14 wells is consistent with the bedrock monitoring wells sampled by Komex in the November 2004 sampling event. Laboratory analysis of groundwater samples for VOCs, SVOCs, and PCBs is proposed under this monitoring program.

Annual maintenance of monitoring wells, such as repair of damaged well caps or concrete surface seals would also be a necessary component of groundwater monitoring. Following the achievement of Site RAOs or upon determination that monitoring is no longer necessary, abandonment/decommissioning of Site groundwater monitoring wells will be required. Monitoring well abandonment would be carried out in accordance with MDNRs requirements.

7.1.4 REVIEW OF SITE CONDITIONS AND RISKS EVERY FIVE YEARS

Review of Site conditions and risks is conducted by the USEPA at five-year intervals and documented in a report. The review is carried out pursuant to a statutory requirement of

CERCLA and the NCP that applies to remedial actions in which COC remain onsite (CERCLA Section 121 (c) and the NCP: 40 C.F.R. 300.430(f)(4)(ii)).

7.2 PROTECTIVENESS OF ALTERNATIVE FB-2

The USEPA may, at its discretion, approve an alternative remedial strategy if a TI waiver is granted. Section 121(b)(1) of CERCLA presents several factors that USEPA is required to consider in its assessment of remedial alternatives. In accordance with the NCP, two threshold criteria must be met in order for an alternative to be eligible for selection:

1. Protectiveness of human health and the environment; and

2. Compliance with all ARARs that have not been waived.

The FB-2 (institutional controls/wellhead treatment/long-term monitoring alternative), described herein, ensures protectiveness of human health firstly by preventing ingestion of impacted groundwater through ICs (preventing the drilling of new wells, or the use of groundwater from existing potable wells onsite), and secondly through provision for wellhead treatment at existing potable water supply wells in the event that they become impacted or new wells are installed for potable water supply use in the future. This was the only exposure route found to pose unacceptable potential future risk to human health (Komex, 2005c).

The institutional controls/wellhead treatment/long-term monitoring alternative will comply with all ARARs, which are not waived. The scope of the TI waiver includes compounds defined as COPC in the BHHRA (Komex, 2005c). Groundwater monitoring will ensure that groundwater in bedrock at the Site continues to comply with all un-waived ARARs.

8 CLOSURE / LIMITATIONS

This report has been prepared for the exclusive use of MEW Site Trust Fund Donors as it pertains to the MEW Site in Cape Girardeau, Missouri. Our services have been performed using that degree of care and skill ordinarily exercised under similar circumstances by reputable, qualified environmental consultants practicing in this or similar locations. No other warranty, either expressed or implied, is made as to the professional advice included in this report. These services were performed consistent with our agreement with our client.

Opinions and recommendations contained in this report apply to conditions existing when services were performed and are intended only for the client, purposes, locations, time frames, and project parameters indicated. We do not warranty the accuracy of information supplied by others or the use of segregated portions of this report.

The purpose of a geologic/hydrogeologic/chemical investigation is to reasonably characterize existing subsurface conditions in the Study Area. In performing such an investigation, it is understood that no investigation is thorough enough to describe all subsurface conditions of interest at a given site. If conditions have not been identified during the investigation, such a finding should not, therefore, be construed as a guarantee of the absence of such conditions at the Study Area, but rather as the result of the services performed within the scope, limitations, and cost of the work performed.

In regard to geologic/hydrogeologic/chemical conditions, our professional opinions are based in part on interpretation of data from discrete sampling locations. It should be noted that actual conditions at unsampled locations may differ from those interpreted from sampled locations.

Respectfully submitted,
KOMEX

Samuel Kramer for

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Project Director

Ralph Beck, R.G.
Senior Geologist

STATE OF MISSOURI
RALPH M. BECK
RG
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REGISTERED GEOLOGIST

MEW Site File
3DISC10411O

Janaka Jayamaha, a Remediation Engineer with Komex, with expertise in contaminant assessment and remediation prepared the report with the title "Fractured Bedrock and Alluvium Groundwater Remediation Feasibility Study, Missouri Electric Works, Cape Girardeau, Missouri," dated July 7, 2005. Ralph M. Beck, a Missouri Registered Geologist, Senior Project Geologist with Komex, reviewed the report. His signature and stamp appear below.

Janaka Jayamaha
Remediation Engineer
July 2005

Ralph M. Beck, R.G.
Senior Geologist
July 2005

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3DISC104111

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Tables

TABLES

TABLE 2.1
CHEMICAL SPECIFIC ARARS FOR TI WAIVER
MISSOURI ELECTRIC WORKS (MEW) SITE

COCs	Observed Maximum Concentration (ug/L)*	ARAR/TCL (ug/L)	Basis (ug/L)
Detected PCB, VOCs and SVOCs			
1,1-Dichloroethane	31	5	RL
1,1-Dichloroethene (Total)	12	7	MCL
1,2,4 Trichlorobenzene	62	70	MCL
1,3-Dichlorobenzene	100	28	Risk-Based
1,4-Dichlorobenzene	120	75	MCL
2-Chlorophenol	9J	10	RL
Aroclor 1260	110**	0.5	MCL
Benzene	83	5	MCL
Bis(2-Chloroethyl) Ether	6J	10	RL
Bis(2-ethylhexyl)phthalate	120	10	RL
Bromodichloromethane	1.9J	80	GTARC
Chlorobenzene	3,200	100	MCL
Chloroform	13	80	GTARC
Naphthalene	8.7J	100	GTARC
N-Nitrosodi-n-propylamine	8.1J	10	RL
Tetrachloroethene	8.6	5	MCL
Trichloroethene	13	5	MCL
Not Detected PCBs, VOCs and SVOCs			
1,1,2,2-Tetrachloroethane	-	5	RL
1,1,2-Trichloroethane	-	5	MCL
1,2-Dichloroethane	-	5	MCL
1,2-Dichloropropane	-	5	MCL
2,4,6-Trichlorophenol	-	10	RL
2,4-Dinitrotoluene	-	10	RL
2,6-Dinitrotoluene	-	10	RL
3,3-Dichlorobenzidine	-	20	RL
4-Bromophenyl Phenyl Ether	-	10	RL
4-Chlorophenyl Phenyl Ether	-	10	RL
4-Chloro-3-methylphenol	-	10	RL
4,6-Dinitro-2 Methyl Phenol	-	50	RL
Aroclor 1016	-	1	RL
Aroclor-1221	-	0.5	MCL
Aroclor-1232	-	0.5	MCL

TABLE 2.1
CHEMICAL SPECIFIC ARARS FOR TI WAIVER
MISSOURI ELECTRIC WORKS (MEW) SITE

COCs	Observed Maximum Concentration (ug/L)*	ARAR/TCL (ug/L)	Basis (ug/L)
Not Detected PCBs, VOCs and SVOCs			
Aroclor-1242	-	0.5	MCL
Aroclor-1248	-	0.5	MCL
Aroclor-1254	-	0.5	MCL
Benzo(a)anthracene	-	10	RL
Benzo(a)pyrene	-	10	RL
Benzo(b) fluoranthene	-	10	RL
Benzo(k)fluoranthene	-	10	RL
bis(2-Chloroethoxy) Methane	-	10	RL
bis(2-Chloroisopropyl) Ether	-	300	GTARC
Carbon Tetrachloride	-	5	MCL
Chlorodibromomethane	-	5	RL
Dibenzo(a,h)Anthracene	-	10	RL
Dibenzofuran	-	10	RL
Hexachloro-1,3-Butadiene	-	10	RL
Hexachlorobenzene	-	10	RL
Indeno(1,2,3-cd)Pyrene	-	10	RL
2-methylnaphthalene	-	10	RL
Nitrobenzene	-	17	GTARC
Pentachlorophenol	-	50	RL
Vinyl Chloride	-	5	RL

Notes:
* = maximum observed concentration up to December 31, 2004.
** = unfiltered sample maximum. Filtered sample maximum 4.5 ug/L.

Abbreviations:
1. COC - Constituent of Concern
2. ARARs - Applicable or Relevant and Appropriate Requirement
3. TCLs - Target Cleanup Levels
4. ug/L - microgram per liter
5. MCL - maximum contaminant level
6. GTARC - Groundwater Target Cleanup Level
7. RL - reporting limit

Figures

MEW Site File
3DISC104118

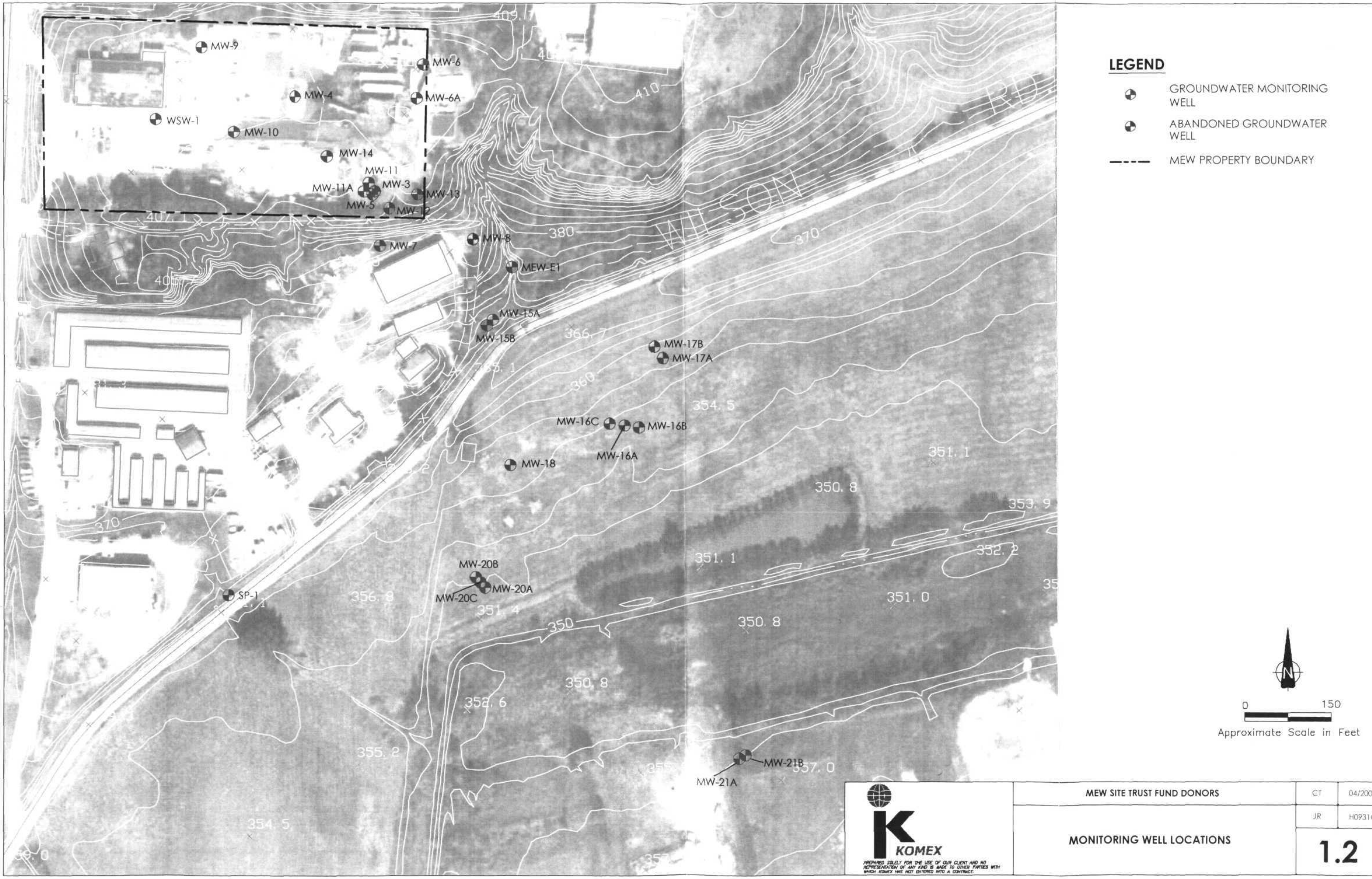
FIGURES

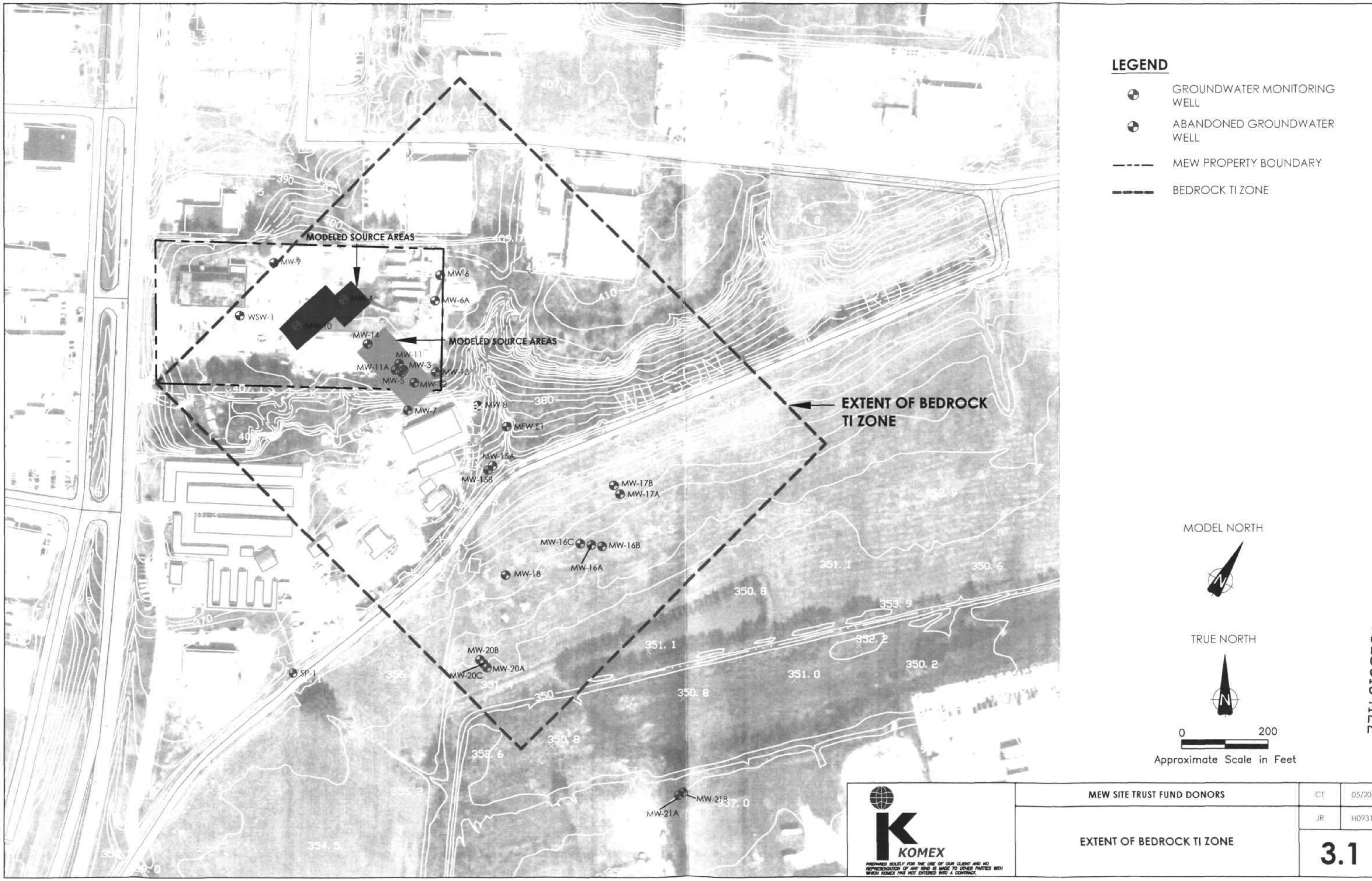
NOTES

1) BASE MAP FROM USGS 7.5 MINUTE CAPE GIRARDEAU QUADRANGLE (1965, REVISED 1993).

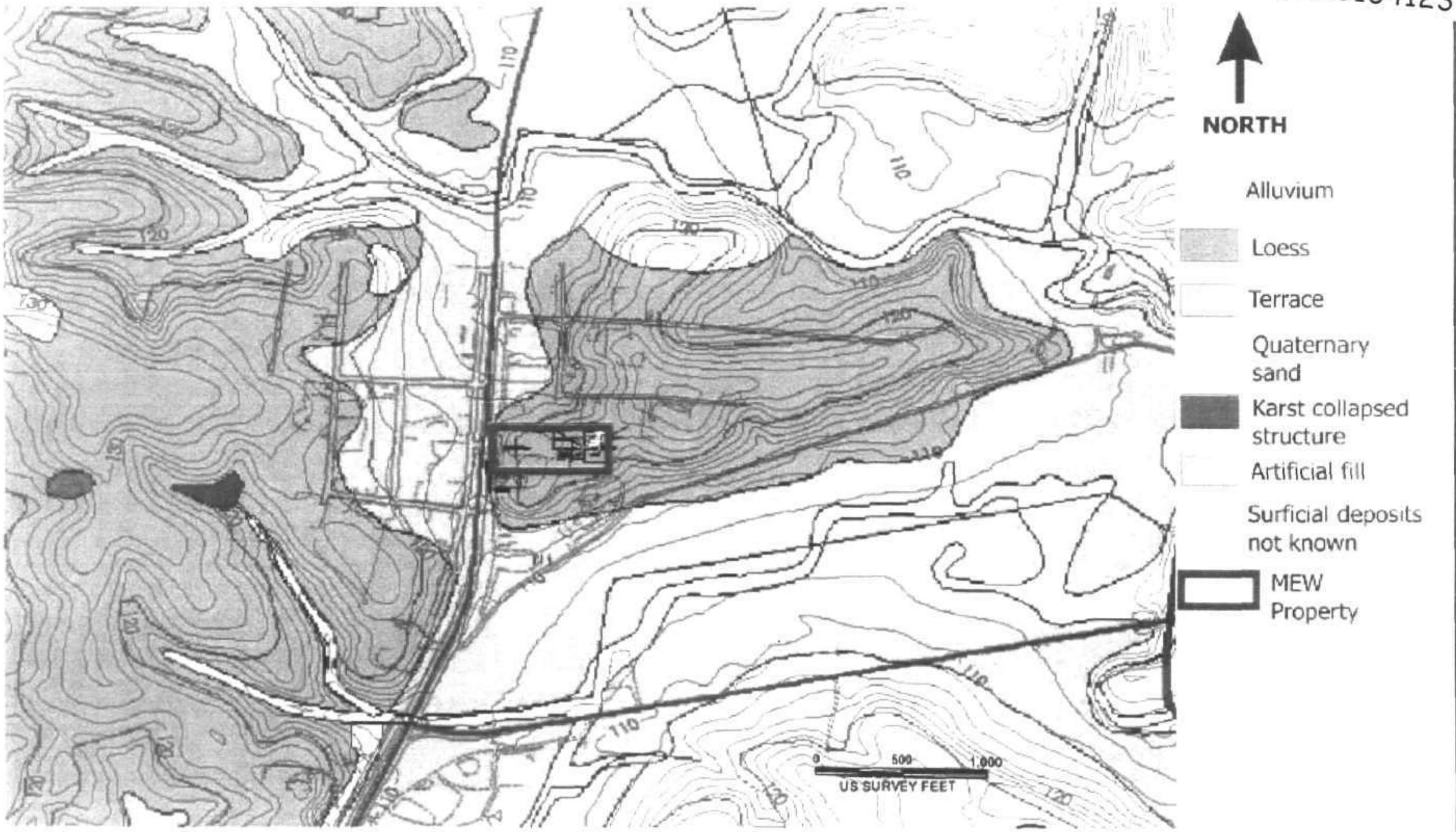
2) ALL LOCATIONS ARE APPROXIMATE.

KOMEX	MEW SITE TRUST FUND DONORS	CT	04/
		JR	HO
	SITE LOCATION MAP	1.1	


LEGEND
GROUNDWATER MONITORING WELL
ABANDONED GROUNDWATER WELL
MEW PROPERTY BOUNDARY
MW-9
MW-6
MW-4
MW-6A
WSW-1
MW-10
MW-14
MW-11
MW-11A
MW-3
MW-13
MW-5
MW-12
MW-7
MW-8
MEW-E1
MW-15A
MW-15B
MW-17B
MW-17A
MW-16C
MW-16B
MW-16A
MW-18
MW-20B
MW-20A
MW-20C
SP-1
MW-21B
MW-21A
WILSON RD.
410
380
370
366.7
360
354.5
351.1
350.8
353.9
352.2
351.0
356.8
351.4
350
352.6
355.2
357.0
354.5
0
150
Approximate Scale in Feet
KOMEX
PREPARED SOLELY FOR THE USE OF OUR CLIENT AND NO REPRESENTATION OF ANY KIND IS MADE TO OTHER PARTIES WITH WHICH KOMEX HAS NOT ENTERED INTO A CONTRACT.
MEW SITE TRUST FUND DONORS
MONITORING WELL LOCATIONS
CT
04/2005
JR
H0931G
1.2


LEGEND
GROUNDWATER MONITORING WELL
ABANDONED GROUNDWATER WELL
MEW PROPERTY BOUNDARY
BEDROCK TI ZONE
MODELED SOURCE AREAS
MODELED SOURCE AREAS
EXTENT OF BEDROCK TI ZONE
MW-9
MW-6
MW-6A
MW-4
WSW-1
MW-10
MW-14
MW-11
MW-11A
MW-3
MW-5
MW-13
MW-7
MW-8
MEW-E1
MW-15A
MW-15B
MW-17B
MW-17A
MW-16C
MW-16B
MW-16A
MW-18
MW-20B
MW-20A
MW-20C
SP-1
MW-21B
MW-21A
WILSON
MODEL NORTH
TRUE NORTH
0
200
Approximate Scale in Feet
KOMEX
PREPARED SOLELY FOR THE USE OF OUR CLIENT AND NO REPRESENTATION OF ANY KIND IS MADE TO OTHER PARTIES WITH WHICH KOMEX HAS NOT ENTERED INTO A CONTRACT.
MEW SITE TRUST FUND DONORS
EXTENT OF BEDROCK TI ZONE
CT
05/2005
JR
H0931G
3.1

MEW Site File
3DISC104123



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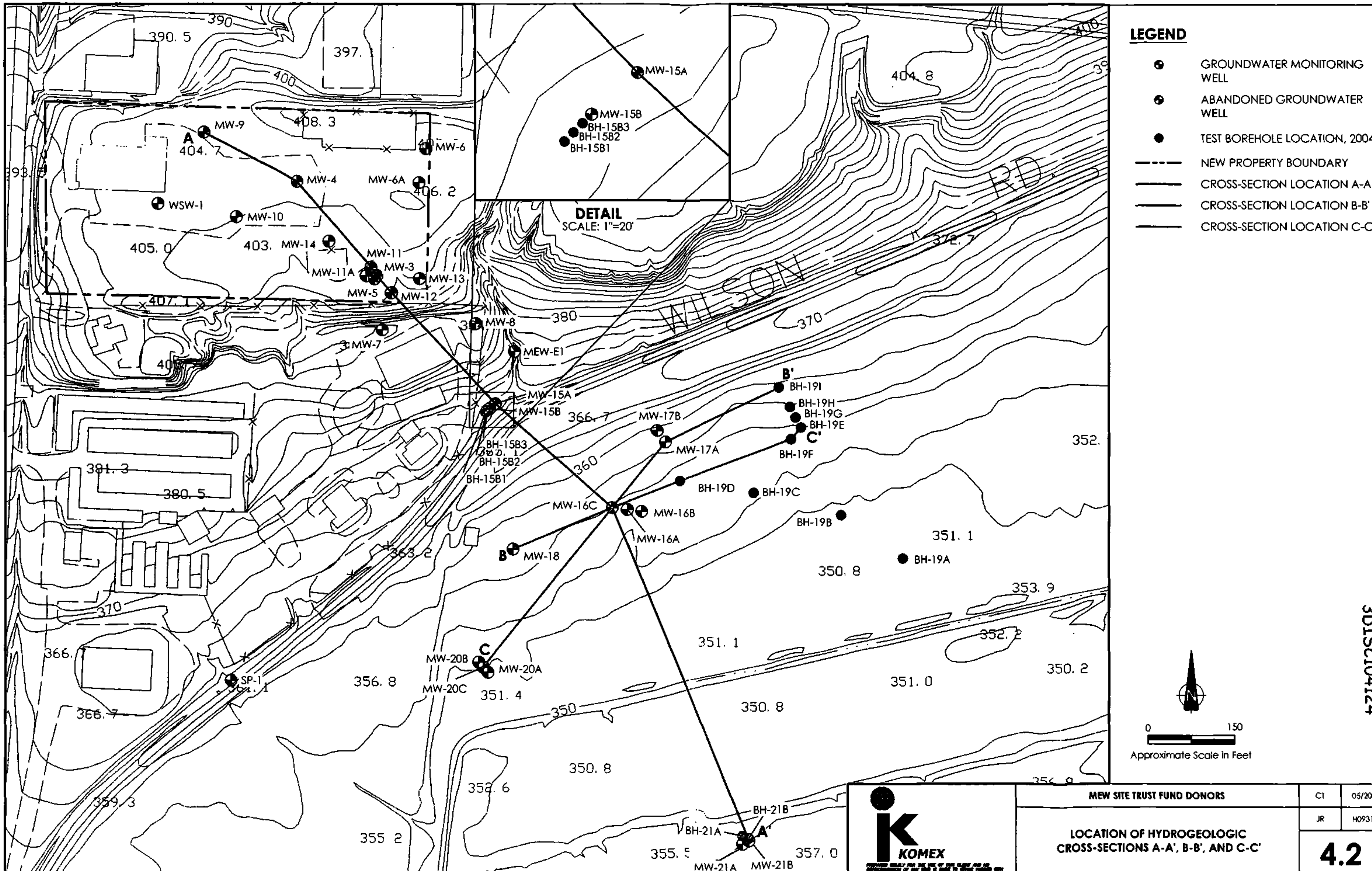
MEW SITE TRUST FUND DONORS

SURFICIAL GEOLOGY (USGS) IN SITE AREA

SWD	04/2005
JR	H0931E
4.1	



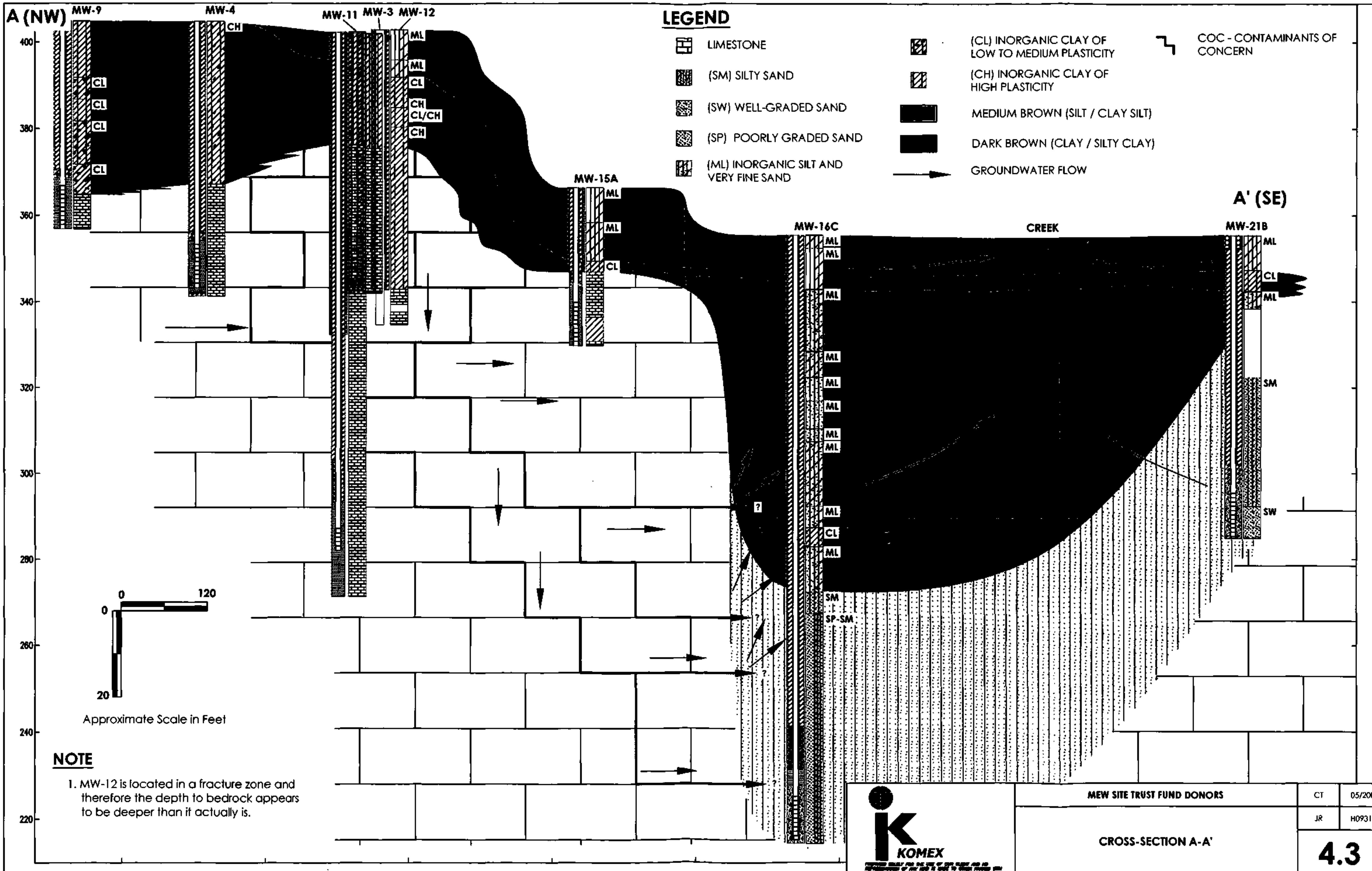
MEW SITE TRUST FUND DONORS

LOCATION OF HYDROGEOLOGIC CROSS-SECTIONS A-A', B-B', AND C-C'

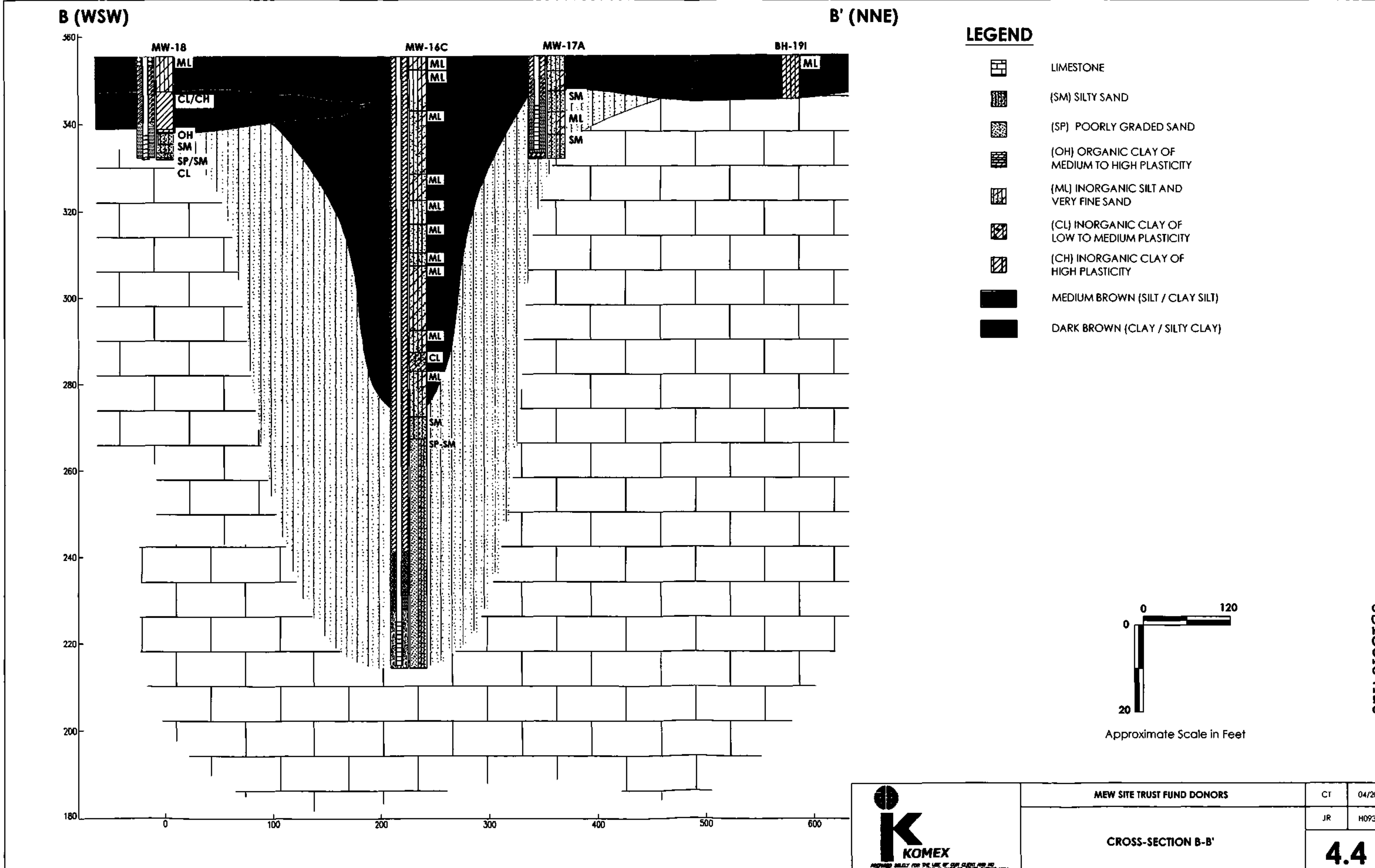
CT	05/2005
JR	H0931G

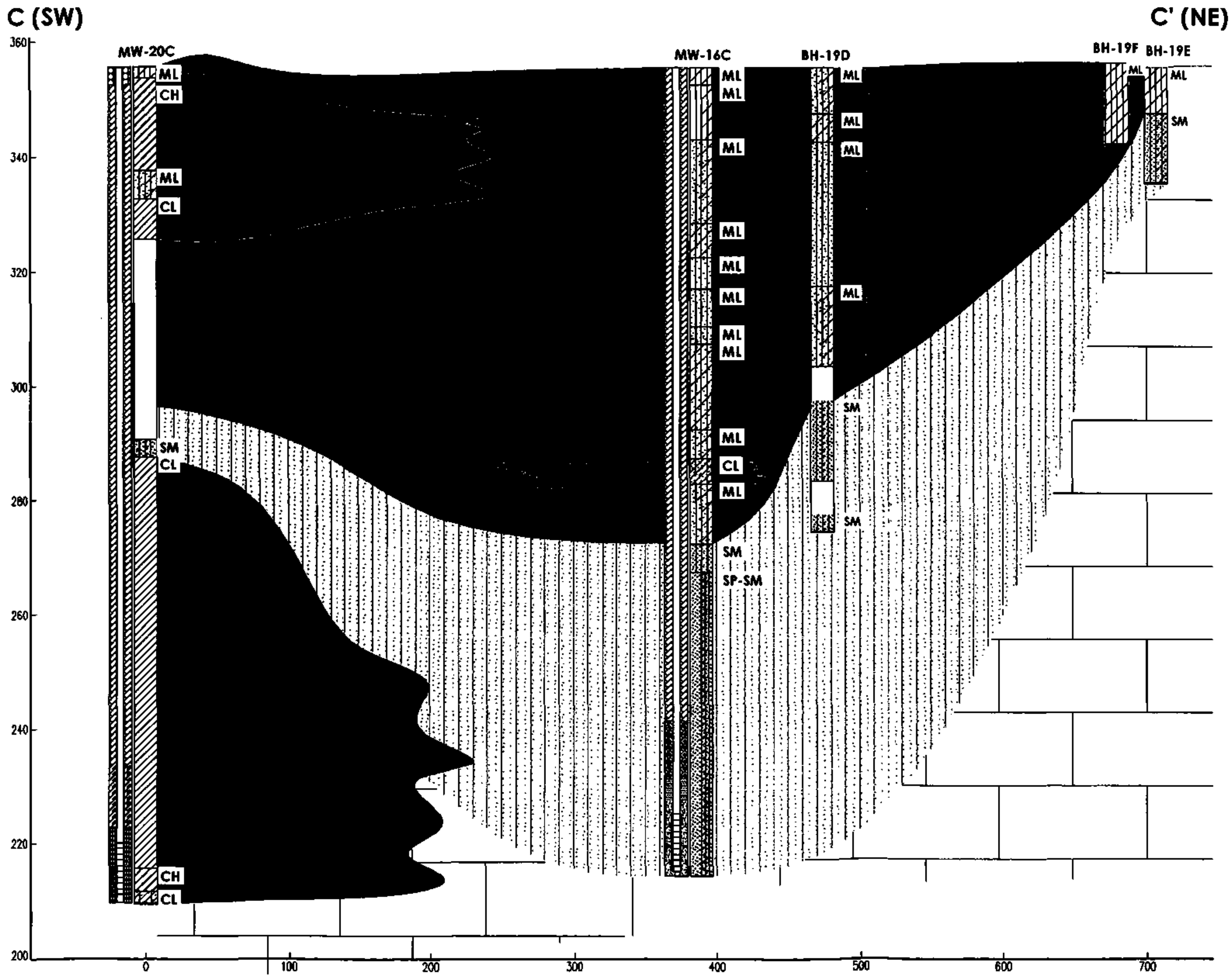
4.2

MEW Site File
3DISC104124



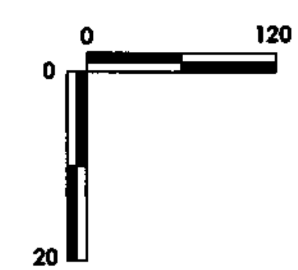
MEW Site File
3DISC104125


B (WSW)
B' (NNE)
MW-18
MW-16C
MW-17A
BH-19I
ML
CL/CH
OH
SM
SP/SM
CL
SM
ML
SM
ML
CL
SP-SM
360
340
320
300
280
260
240
220
200
180
0
100
200
300
400
500
600
LEGEND
LIMESTONE
(SM) SILTY SAND
(SP) POORLY GRADED SAND
(OH) ORGANIC CLAY OF MEDIUM TO HIGH PLASTICITY
(ML) INORGANIC SILT AND VERY FINE SAND
(CL) INORGANIC CLAY OF LOW TO MEDIUM PLASTICITY
(CH) INORGANIC CLAY OF HIGH PLASTICITY
MEDIUM BROWN (SILT / CLAY SILT)
DARK BROWN (CLAY / SILTY CLAY)
0
120
0
20
Approximate Scale in Feet
KOMEX
MEW SITE TRUST FUND DONORS
CT
04/2005
JR
H0931G
CROSS-SECTION B-B'
4.4



LEGEND

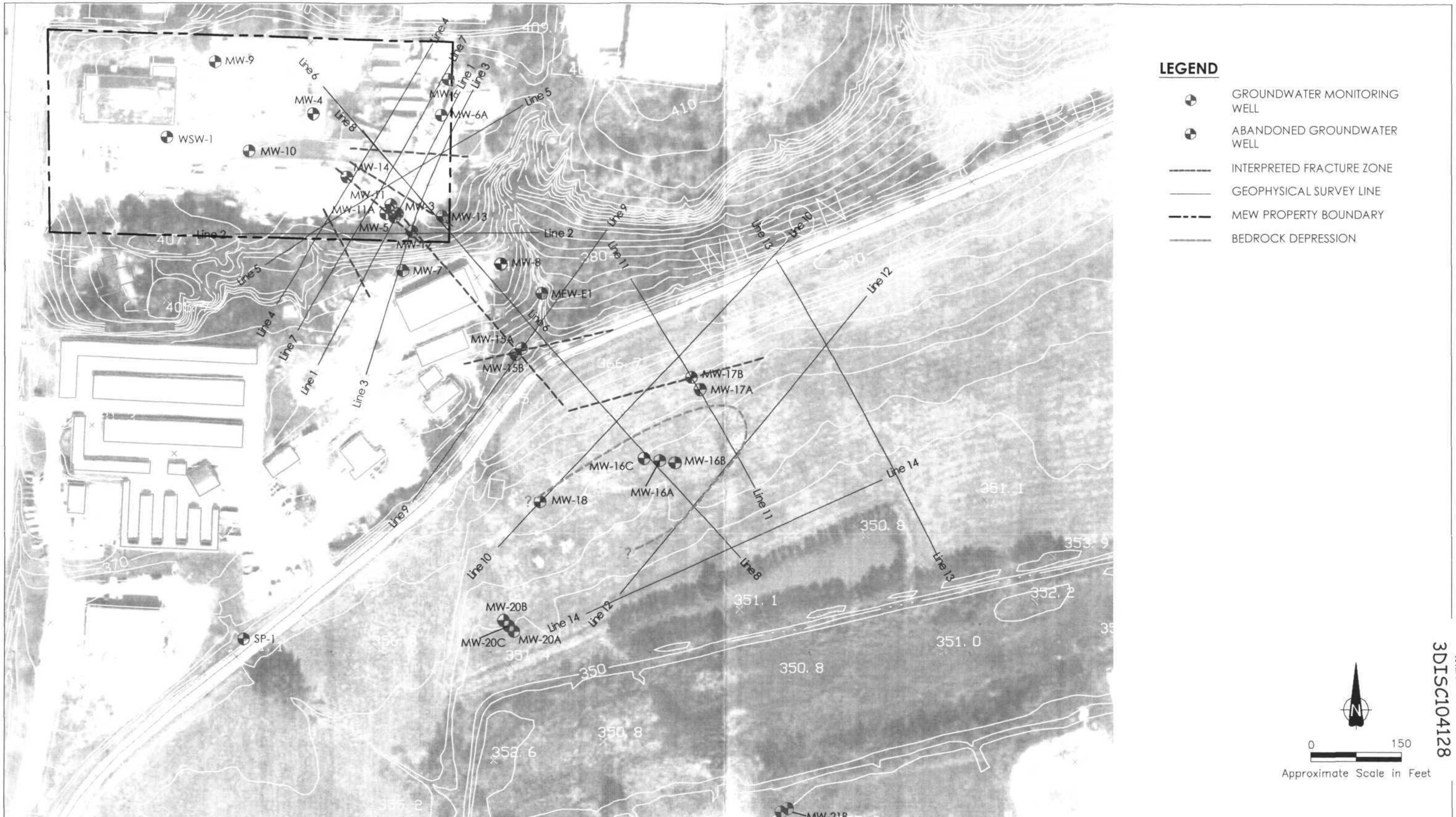
- LIMESTONE
- (SM) SILTY SAND
- (SP) POORLY GRADED SAND
- (ML) INORGANIC SILT AND VERY FINE SAND
- (CL) INORGANIC CLAY OF LOW TO MEDIUM PLASTICITY
- (CH) INORGANIC CLAY OF HIGH PLASTICITY
- MEDIUM BROWN (SILT / CLAY SILT)
- DARK BROWN (CLAY / SILTY CLAY)



Approximate Scale in Feet

3DISC104127
MEW Site File

KOMEX	MEW SITE TRUST FUND DONORS	CT	04/2005
		JR	H0931G
	CROSS-SECTION C-C'	4.5	



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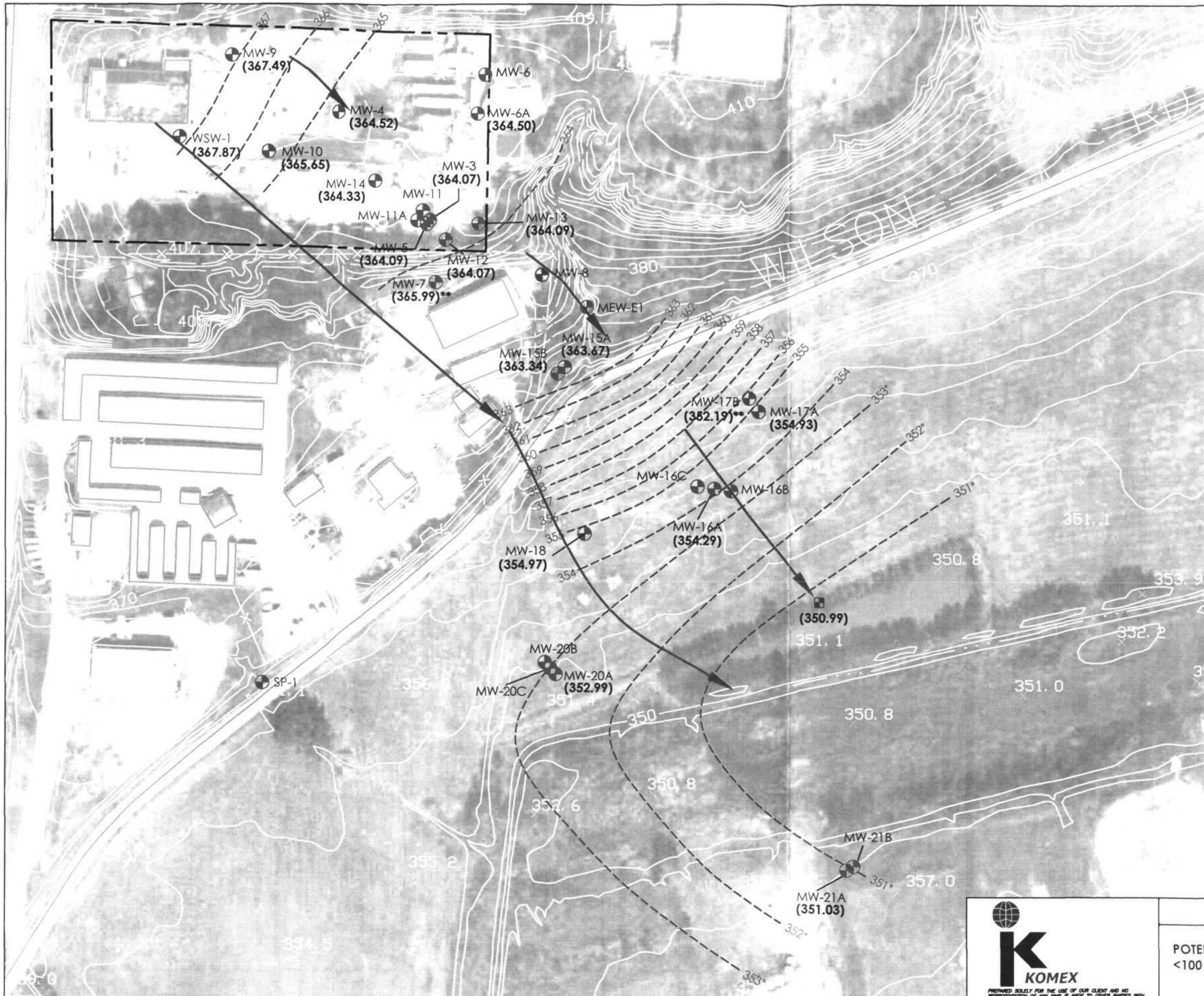
MEW SITE TRUST FUND DONORS	CT	04/2005
INTERPRETED BEDROCK STRUCTURE AND FRACTURE TRENDS	JR	H0931G
	4.6	

MEW Site File
3DISC104128



LEGEND

	GROUNDWATER MONITORING WELL
	ABANDONED GROUNDWATER WELL
	WATER ELEVATION COLLECTION POINT AT THE POND
	POTENTIOMERTRIC CONTOURS
	MEW PROPERTY BOUNDARY
	GROUNDWATER FLOW
(354.29)	GROUNDWATER LEVEL (FEET ABOVE MEAN SEA LEVEL)
*	CONTOUR INTERPRETATION BASED ON CONCEPTUAL MODEL
**	GROUNDWATER LEVEL NOT USED IN CONTOURING

N

0 150

Approximate Scale in Feet

MEW Site File
3DISC104129

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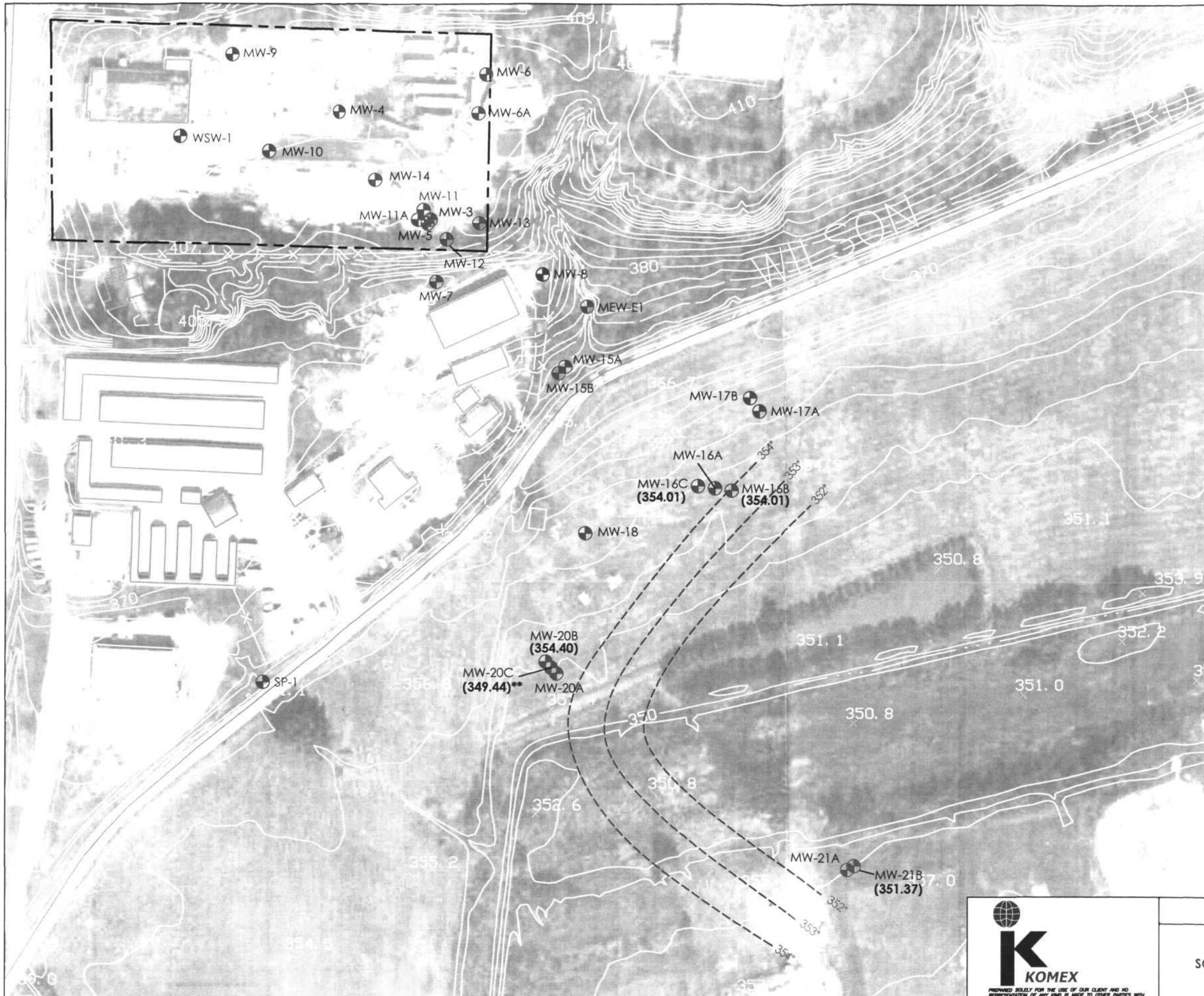
MEW SITE TRUST FUND DONORS	CT	05/2005
POTENTIOMETRIC SURFACE FOR WELLS SCREENED <100 FEET BGS IN BEDROCK AND <25 FEET BGS IN ALLUVIUM FOR NOVEMBER 15, 2004	JR	H0931G
		4.7



LEGEND

●	GROUNDWATER MONITORING WELL
●	ABANDONED GROUNDWATER MONITORING WELL
--------	POTENTIOMETRIC CONTOURS
— - — -	MEW PROPERTY BOUNDARY
(351.37)	GROUNDWATER LEVEL (FEET ABOVE MEAN SEA LEVEL)
*	CONTOUR INTERPRETATION BASED ON CONCEPTUAL MODEL
**	GROUNDWATER LEVEL NOT USED IN CONTOURING

N

0 150

Approximate Scale in Feet

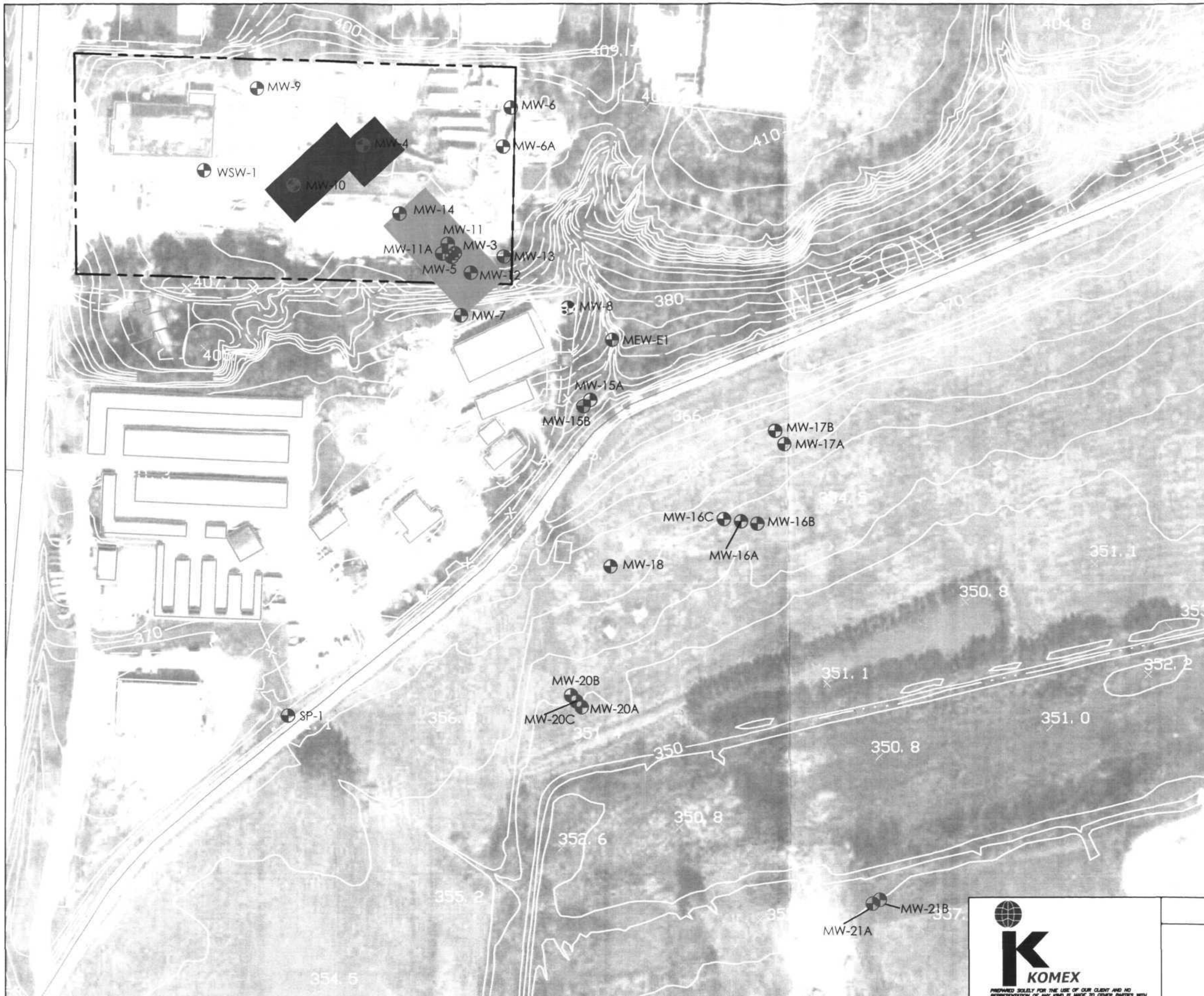
KOMEX

MEW SITE TRUST FUND DONORS

POTENTIOMETRIC SURFACE FOR WELLS SCREEND 50 TO 150 FEET BGS IN ALLUVIAL SEDIMENTS FOR NOVEMBER 15, 2004

CT	05/2005
JR	H0931G

4.8



LEGEND

- GROUNDWATER MONITORING WELL
- ABANDONED GROUNDWATER WELL
- MEW PROPERTY BOUNDARY

NOTES

1) SOURCE AREA 1 SHOWN IN GREEN.
2) SOURCE AREA 2 SHOWN IN BLUE.

N

0 50
Approximate Scale in Meters

KOMEX

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MEW SITE TRUST FUND DONORS	CT	05/2005
	JR	H0931G
LOCATIONS OF MODELED SOURCE AREAS	4.9	

LEGEND

- GROUNDWATER MONITORING WELL
- ABANDONED GROUNDWATER MONITORING WELL
- MEW PROPERTY BOUNDARY
- CONCENTRATIONS ABOVE MAXIMUM CONTAMINANT LEVEL

NOTES

1. 1,1-DCE-16 = concentration in μg/L
2. N/D = non-detection of constituents of concern
3. MW-19 was not installed.
4. MW-1 and MW-2 have been abandoned, but the exact location is not known.
5. N/S = not sampled
6. μg/L = micrograms per liter

0 150
Approximate Scale in Feet

MEW Site File
3DISC104132

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MEW SITE TRUST FUND DONORS

GROUNDWATER CONSTITUENTS OF POTENTIAL CONCERN CONCENTRATIONS FOR NOVEMBER 2004

CT 04/2005
JR H0931G

4.10